Final Report: Littoral Drifter for Sensing Properties of Shallow Waters and Sediments

Topic: N05-T027

Riverine Drifter Field Trials July 10, August 13 and September 10, 2008

Clearwater Instrumentation, Inc. 304 Pleasant St., Watertown, MA 02472

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14. ABSTRACT
Littoral Drifter has been designed, constructed and tested. This small drifter (less than 2kg) measures, records and telemeters complete information on a shallow water environment: drifter velocity, 3-D velocities of the underlying water, depth and bottom quality. Summary data are telemetered over the Iridium system. All data are internally recorded and can be downloaded

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3 October 2005

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Subject: Final Report: Littoral Drifter for Sensing Properties of Shallow Waters and Sediment
Contract: N00014-07-C-0270

Dear Dr. Vincent:

I am please to submit out final report on the contract referenced above. Please contact me if you have any questions.

Best regards,

W. Gary Williams

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1.0 Performance Characteristics

Shallow water environments that exist where rivers and estuaries meet the ocean are often characterized by regimes of energetic currents and shallow rapidly varying bathymetry which in the case of easily mobilized sediments can by spatially modified over short periods. The Riverine drifter has the observational tools to measure the characteristics of the estuarine environment. It combines the position accuracy of GPS locations, 3-dimensional current measuring ability of an Acoustic Doppler Profiling Current meter, depth and bottom characterization of high precision acoustic pinging, and high data rate Iridium telemetry. All of these capabilities are in a compact, stable drifter that weighs less than 10 pounds and that has a very low profile at the sea surface. In addition, this early model of the Riverine Drifter has internal storage that allows many hours of data to be stored and retrieved at a later time to facilitate development of sampling and analysis strategies.

Riverine Drifter generates and internally records a torrent of high quality data describing the aquatic environment it drifts through:

- 2 second GPS positions, time, elevation (ellipsoid and mean sea level), Speed Over Ground, Course Over Ground, climb rate, clock drift, satellite constellation, Horizontal Dilution of Precision, and Figure of Merit.
- 2 second averages of ADCP data:

  Velocities east, north, and up (magnetic reference)

  Acoustic signal strength for three sensors

  Depth and acoustic return quality

  Instrument heading (magnetic), tilt, roll

  Status,: battery, internal temperature

A distillation of this information is sent to the user in Iridium data messages sent every ten minutes:

- GPS position, seconds of the year
- Complete Aquadopp data message
- 60 10-second samples of depth and signal return quality

2.0 Subsystems

Riverine Drifter is an integration of proven sensors and electronic systems into a CODE drifter housing. The electronic systems include:

- Nortek Riverine Drifter Aquadopp shallow water ADCP with fourth sensor (added explicitly for Riverine Drifter) looking vetically downward
- ClearSat-4.0 microprocessor-base instrument controller
- Navman Jupiter 31 GPS engine
- NAL Research 9601 Iridium Modem
- Dual-band (GPS and Iridium) antenna

All of these subsystems are integrated into a reduced-size CODE drifter hull that can self-deploy from a compact shape where the sails and antenna are snugged up against the hull. Hull components are fabricated from anodized 6061 aluminum. The interior electronics bay of the hull is protected by double o-ring seals at both ends of the hull. This drifter is extremely stable at the water surface; it moves with the surface with very little motion above or below the surface maintaining a vertical aspect and exhibiting little rotation over tens of minutes.

2.1 Nortek Aquadopp

Explanations from Sven Nylund (personal communication) on the distance and quality measurement made from the fourth head.

“The actual distance value is the de-spiked average over the first 100 pings along the fourth beam during the average interval. This means that if you do long averages at high measurement loads, the distance value might not cover the whole average interval. It is possible for the distance measurement to exceed the sampling depth for the Aquadopp. The regular [Aquadopp] setup is adjusted the 25 degree angle of the transducers that are used for velocity measurements. Since the fourth transducer is already is in the vertical this increases the range by 10%. In addition, the blanking distance for the distance measurement is effectively one cell size larger so 0.5 meters as opposed to 0.2 meters for the velocity in your case. Finally the regular setup is done for a nominal speed of sound of 1500 m/s so if the actual speed of sound exceeds that, the distance output can increase slightly.”

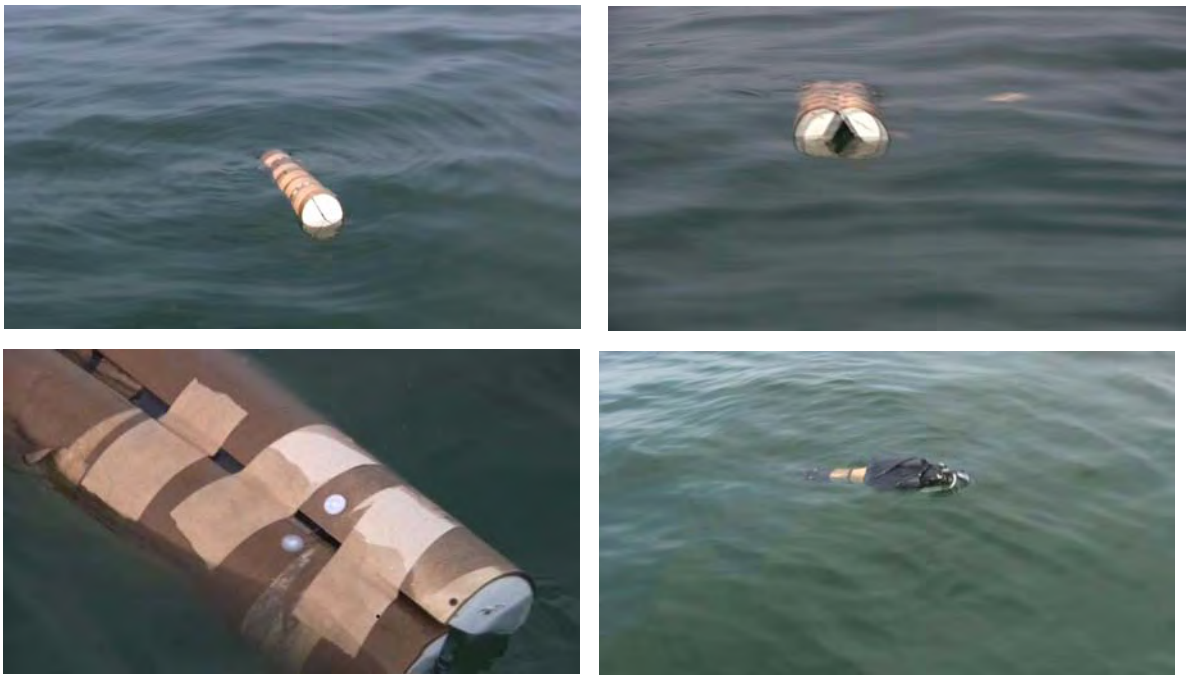
“The quality parameter is the average of the bottom echoes that were used to arrive at the averaged distance measurement. For each ping we measure an amplitude profile which we then apply a match filter to. The match filter looks for the leading edge of the bottom echo in that it has an edge shape (effectively a flat portion first and a steep sloping line to follow). The echo from the bottom itself will typically saturate the receiver at the peak which means that the highest quality factor that is output will be when the signal return from the water [column] is at its lowest level (the noise level) and the slope from the bottom echo matches the slope of the match filter.... this means that for constant bottom conditions the quality value will increase with increasing distance and it will decrease with increasing turbidity (more particles in the water means higher signal return from the water [column]). Now, if the [return signal] slope changes with bottom conditions and/or there is enough dynamic range so that the receiver does not saturate at the peak of the bottom echo there could be information in the quality parameter about the bottom conditions. But there must be some adjustment depending on the signal level from the water [column] for this to work over varying distances and turbidity. The regular amplitude profiles could be used for this.

3.0 Data Processing

Data recorded by Riverine Drifter and the processing required are described in the Appendix Data and Processing.

4.0 Field Testing

Riverine Drifter has been tested in the field in three deployments in Boston Harbor. Boston Harbor offers a variety of shallow water environments and conditions of winds, waves and tidal currents. The interior of the Boston Harbor contains many large areas of clay flats and mud flats. Moving toward the Outer Harbor one encounters scoured areas of exposed rock and ledge. The initial 2 hour deployment was on 19 July 2008 (series 01). This was followed by August 13, 2008 when the conditions were for the most part calm, sunny but with strong, ebbing tidal currents.The last deployment was 10 September 2008.



4.1 Initial Trial 19 July 2008.

The purpose of this initial field test was to verify self-deployment and to test the operation of GPS data collection in the RD internal memory and to verify the operation of the Aquadopp 3-dimensional current measuring system.

4.1.1 Self-deployment




4.1.2 Deployment East of Spectacle Island

Riverine Drifter was pulled from the water and redeployed between Spectacle Island and Long Island to record location information and Aquadopp 3-dimensional current information. The following pictures shows the Riverine Drifter track as displayed in Google Earth. The first show the location of Riverine Drifter at various times while the other is the picture of track as displayed from 1 Hz GPS positions.


Spectacle Island
Start 9:44
9:49
9:54
9:59
10:04
10:09
10:14
End 10:32
Long Island
Sculpin Ledge
© 2008 Europa Technologies
© 2008 Tele Atlas
Image MassGIS, Commonwealth of Massachusetts EOEA
Google


Image MassGIS, Commonwealth of Massachusetts EOEA
© 2008 Tele Atlas
Google

4.1.3 Deployment 19 July 2008 Discussion

The figures in the Appendix shows the Aquadopp beam signal strength for all heads. The maximum in the lower sections essentially conforms to the reflection off the bottom underneath Riverine Drifter. The bottom is flat at 4.6 m until a gouge extending to 6.2 meters is encountered. Speeds vary from 0.2 to 0.3 meters per second. There is a minimum in the speed over the gouge. The direction of flow is south to southwest, except over the gouge which appears to be oscillation to the east and west.

4.2 Second Deployment 13 August 2008

The goal of the second deployment was to launch Riverine Drifter into as many different environments as possible. To this end the environments investigated included:

- Rocky with high tidal currents
- Near shore areas of varied bottom conditions
- Shipping channels with high tidal velocities
- Tidal flats with hard clay bottom

In all twelve different deployments were made and data were returned for all deployments. Selected results are shown below. GPS data were recorded on the Riverine Drifter SD card and Aquadopp data were recorded by the Aquadopp.

4.2.1 Main Shipping Channel Deployment 01

Depth of the shipping channel varied from about 6 to 5 meters in the direction of flow which was to the northwest turning toward north at velocities decreasing from about 40 cm/s to 20 cm/s. Please refer to the Figure appendix.

4.2.2 East of Peddocks Island 02

Riverine Drifter was launched east of Peddocks Island and was carried to the north by the strong tidal current ebbing through Hull Gut. Depths were 4.5 meters until the drifter passed though the Gut where the depth quickly exceeded its range of 6.7 meters. Velocities are gradually increase from 5 cm/s to the northeast to 20 cm/s toward the north as the drifter approaches the deep water in the Gut. Once in the Gut the velocities reach 30 to 35 cm/s to the north turning to the northwest. There is a vertically banded structure in the velocity indicating some oscillations of the current.

4.2.3 Between Boston Light (south) and (Greater Brewster Island (north) 05

Riverine Drifter was released to the west of a rocky ledge that come within a few meters of the surface. The tidal current was ebbing to the east. The GPS track displayed in Google Earth shows is passing over the ledge and skirting the boundary with deeper water. The velocity starts out at 30 cm/s to the east then accelerates to 60 cm/s over the ledge. It then slows to 30 to 40 cm/s and turns to the northeast.

4.2.4 Hull Gut

This is a narrow channel between Hull and Peddocks Island. Tidal velocities can run quite high here as the large volume of water in the more landward areas drain toward the open ocean. The Gut is more than 30 feet deep in the area crossed by Riverine Drifter, so the amplitude chart displayed here does not indicate the bottom.The water is moving

at 40 cm/s toward the west as the drifter rounds the most western extension of Hull then accelerates to between 80 and 100 cm/s as it passes through the Gut turning toward the north. There appears to be some pulsing of the current on a scale of about two minutes.

4.2.5 West of Bumkin Island over Tidal Flats 10

The amplitude plot shows Riverine Drifter passing over flat bottom then crossing a boat channel. The velocity varies between 15 to 30 cm/s to the northwest until Riverine Drifter passes over the channel when the velocity slows to 10 to 15 cm/s. The velocity picks up again after it crosses the channel. The current is surging at about a 4 -5 minute cycle.

4.3 Field Deployments 10 September 2008

Since Nortek had provided firmware to activate the fourth acoustic sensor head the goal was to visit a variety of shallow water environments to obtain data from the bottom pinger which yields information on the depth to the bottom and quality of the response. Many of the same locations visited on 13 August were revisited on this day.

4.3.1 North of Little Brewster Island (Boston Light) 05

Riverine Drifter was launched to the west of the rocky ledge less than 100 m from the Boston Light dock. For the first time it is possible to compare the strong amplitude signal with the depth information from the Aquadopp pinger. It is clear that the am[plitude signal indicates the bottom to within the accuracy of the cell dimension. The depth signal is quite noisy because the surface was choppy. A 5-second average removes some of the wave noise, but it is evident that the bottom is quite rough. Indeed, the chop was around 1 foot and the scatter is about the same number. We can assume that these are large rocks and ledges as the environment is too energetic to allow deposition of soft material. Velocities start at about 30 cm/s just west of the ledge and accelerate to 50 cm/s over the ledge. After that velocities are 30 to 40 cm/s and the flow slowly turns to the southeast. There is evidence of some periodic signal with a period of 4 to 5 minutes.

4.3.2 Pt. Allerton south of Beach on Hull 06

Riverine Drifter was deployed less than 100 meters off the sandy beach on Allerton Point. the area is protected from the northwest wind and was very calm. Currents were light. The amplitude indicates the bottom at 2.2 to 2.5 meters. The depth is much more distinctly drawn with the pinger as there was little chop to disturb the drifter. Currents are around 10 cm/s to the east with a little excursion to the southeast.

4.3.3 Bumpkin Island Tidal Flats 07

Riverine Drifter was place west of Bumpkin Island over flats.The amplitude indicates that the bottom is at about 3 meters and this is confirmed by the depth measurement which is at 4 meters with a little scatter due to the light chop present that day. The currents are low at 10 to 15 cm/s. Although the track is trends to the southwest the display of heading is more mixed.

4.3.4 Moon Island Mud Flats 08

This is a low energy environment with a muddy bottom at about 2 meters as indicated by the amplitude graph; the depth measurement shows a bottom at about the same depth.Velocities are about 10 to 15 cm/s to the southeast.

4.3.5 U Mass Marine Ops Boat Basin 09

This is a low energy environment with heavy sedimentation which has created a very muddy bottom.There is a dredged channel to the docks. The amplitude graph shows that the bottom shown by the maximum response is quite similar to the depth measurement from the fourth Aquadopp sensor. The current was flowing at 10 to 15 cm/s to the east and southeast.

5.0 Conclusions

Riverine Drifter is a viable tool for sensing properties of shallow waters. These goals have been accomplished. To build the Riverine Drifter we have:

1. Through cooperation with Nortek obtained a redesigned Aquadopp acoustic sensor head that includes a fourth, vertically positioned sensor for recording depth and bottom characteristics.
2. Integrated the Nortek Aquadopp head into a drifter
3. Modified the ClearSat-1 drifter hull to be smaller and to adapt with the Aquadopp sensor head. This required the design of an adapter plate to allow pass through of Aquadopp sensor leads, and the mounting of the drifter collapsible spars for drogue planes while maintaining the water-tight integrity of the hull.
4. Fit the Aquadopp PC board into the hull and moved it above the battery pack at the bottom of the hull to maintain buoyancy trim for the drifter
5. Integrated the ClearSat-4.0 controller, Iridium 9601 modem, NavMan Jupiter 31 GPS engine and RF splitter (isolating GPS and Iridium) into the remaining hull space.
6. Designed a compact dual band antenna to permit reception of GPS signals and communication with Iridium satellites.
7. Incorporated waterproof connectors for configuring the instrument for field work, downloading data, and for recharging batteries.

Riverine drifter measures, processes and internally records a high volume of data on the shallow water environment and transmits a processed messages of recent measurements. The measurement functions and processing include:

1. 2 Hz GPS measurements of many navigation parameters including time, position and velocity
2. 2 Hz Aquadopp measurements of 3-dimensional currents, distance to bottom and bottom quality signal.
3. Parsing and evaluating each 212-byte Aquadopp message
4. Storage of GPS measurements and Aquadopp messages on a 212 MB SD card. Aquadopp messages can be reformed into time series data files corresponding to a1, a2, a3, v1, v2, v3, and sensor files.
5. Firmware for downloading data from the internal SD card and Aquadopp data storage
6. Assembly of a 337-byte message for transmission including latest GPS, 60 distance quality pairs (10Hz) and the latest Aquadopp sensor message.
7. Transmission of the 337-byte status message by Iridium

Riverine Drifter was deployed multiple times in Boston Harbor where it collected and stored data on drifter track water column dynamics and bottom conditions. Many of these deployments have been discussed in the previous sections.

Suggestions for remaining work:

1. After review of field studies, finalization of processing to reduce the data stream being passed through the Iridium satellite link.
2. Development of algorithms for refining the sediment characterization
3. Development of software for user display of the Riverine Drifter data stream

6.0 Appendices

TABLE 1. Field Deployment 19 July 2008

This initial deployment verified the self-deployment from the Riverine Drifter container and was the first test of GPS internal recording and Aquadopp operation

The weather was clear with little wind. Average tidal currents were expected.

1. Launched in self-deployment case.

- In: 0810 EDT, 1110 UT
- 0835 Riverine Drifter has deployed from the case and is operating.
- Out: 0930 EDT
- Weather sunny and light breeze
- Waves; very light chop
- Depth:
- Bottom:

2. Between Spectacle Island and Long Island

- In: 0943 EDT, 1343 UT
- Out:1032 EDT, 1432 UT
- Out: 0930 EDT
- Weather sunny and light breeze
- Waves; very light chop
- Depth:
- Bottom:

TABLE 2. Field Deployments 13 August 2008

Riverine Drifter now has logging capability for GPS and Aquadopp data. The goal is to operate aquadopp in a variety of coastal shallow water environments with varying conditions of tidal currents and bottom conditions.

Strong tidal currents are expected on this sunny, calm summer day.

1. Lower Middle (Main Shipping Channel)

- In: 0833 EDT, 1233 UT
- Out: 0849 EDT, 1249 UT
- Weather: sunny, light breeze
- Waves: very light chop
- Depth: 12 feet
- Bottom: hard clay and rock

2. Hull Gut by Peddock Island

- In: 0904 EDT, 1304 UT
- Out: 0948 EDT, 1348 UT
- Weather: sunny, light breeze
- Waves: very light chop
- Depth: 16 feet
- Bottom: cobbles and silt

3. Prince Head off Peddock Island

- In: 0957 EDT, 1357 UT
- Out: 1010EDT, 1410 UT
- Weather: sunny, light breeze
- Waves: very light chop
- Depth: 11.3 feet
- Bottom: sand and mud

4. Prince Head off Peddock Island (a little further from land)

- In 1011 EDT, 1411 UT
- Out: 1032 EDT, 1432 UT
- Weather: sunny, light breeze

- Waves: very light chop
- Depth: 13 feet
- Bottom: sand and mud

5. Between Boston Light and Greater Brewster Island (Riverine Drifter runs over a rocky shoal where water depth is 6-8 feet)

- In: 1044 EDT, 1444 UT
- Out: 1108 EDT, 1508 UT
- Weather: sunny, light breeze
- Waves: swell 1 foot, 20 sec.
- Depth: 19 to 8 to 19 feet
- Bottom: rocky

6. Just north of Greater Brewster Island (between Calf Island and Greater Brewster Island. Drifts very close to Calf Island)

- In: 1113 EDT, 1513 UT
- Out: 1146 EDT, 1546 EDT
- Weather: sunny, light breeze
- Waves: swell 1 foot, 20 sec.
- Depth: 16.5 feet, varying
- Bottom: sandy, pebbly, hard bottom

7. Hull Gut (high tidal velocity, turbulent water)

- In: 1158 EDT, 1558 UT
- Out: 1214 EDT, 1614 UT
- Weather: sunny, light breeze
- Waves: light chop
- Depth: 25 feet
- Bottom: hard

8. Closer into Hull (about 50 m off shore. Tidal current high with visible turbulence)

- In: 1217 EDT, 1617 UT
- Out: 1233 EDT, 1633 UT
- Weather: sunny, light breeze
- Waves: light chop

- Depth: 48 feet
- Bottom: hard

9. Bumpkin Island (Hingham Yacht Club)

- In: 1243 EDT, 1643 UT
- Out: 1302 EDT, 1702 UT
- Weather: wind east 5-8 m.p.h.
- Waves: light chop
- Depth: 11 feet
- Bottom: sand and mud, soft

10. Off the north end of Bumpkin Island

- In: 1308 EDT, 1708 UT
- Out: 1354 EDT, 1754 UT
- Weather: wind east 5-8 m.p.h.
- Waves: light chop
- Depth: 9 - 10 feet
- Bottom: sandy, muddy, soft

11. Off Prince Head Peddock Island

- In: 1358 EDT, 1758 UT
- Out: 1410 EDT, 1810 UT
- Weather: wind east 5-8 m.p.h.
- Waves: light chop
- Depth: 10 feet
- Bottom: pebbly, hard

12. Just off Prince Head Peddock Island

- In: 1415 EDT, 1815 UT
- Out: 1458 EDT, 1858 UT
- Weather: wind east 5-8 m.p.h.
- Waves: light chop
- Depth: 6.5 Feet
- Bottom:

TABLE 3. Field Deployments 10 September 2008

Purpose: Nortek firmware upgrades to Aquadopp head turned on sampling on the fourth sensor. This permits measurements to be made for depth and for a quality measurement that is related to bottom conditions. The goal is to visit several locations with varying bottom conditions and to collect data that will demonstrate the effect of those conditions on the quality measurement.

Conditions; Weak tidal currents are anticipated because of the less than normal tidal range.

Data Files: 20080903*

1. Boston Light (between Greater Brewster and Little Brewster Islands) 03

- In: 827 EDT, 1227 UT
- Out: 0832 EDT, 1231 UT
- Weather: sunny, winds WNW 15 -20 kts
- Waves: 1 foot chop
- Depth: 20 feet, varying
- Bottom: rocky ledge

2. Boston Light (between Greater Brewster and Little Brewster Islands) 04

- In: 0839 EDT, 1239 UT
- Out: 0849 EDT, 1249 UT
- Weather: sunny, winds WNW 15 -20 kts
- Waves: 1 foot chop
- :Depth: 9 - 10 feet
- Bottom: rocky ledge

3. West of Little Brewster 05

- In: 0852 EDT, 1252 UT
- Out: 0915 EDT, 1315 UT
- Weather: sunny, winds WNW 15 -20 kts
- Waves: 1 foot chop
- Depth: 12 feet
- Bottom: rocky ledge

4. Point Allerton just off south shore of Hull 06

- In: 0930 EDT, 1330 UT
- Out: 0947 EDT, 1347 UT
- Weather: sunny, wind 5- 10 kts
- Waves: none (protected)
- Depth: 8 feet
- Bottom: sandy

5. West of Bumpkin Island 07

- In: 0953 EDT, 1353 UT
- Out: 1023 EDT, 1423 UT
- Weather: sunny, wind 10-15 WNW
- Waves: 1 foot chop
- Depth: 11 feet
- Bottom: hard clay

6. South of Moon Island 08

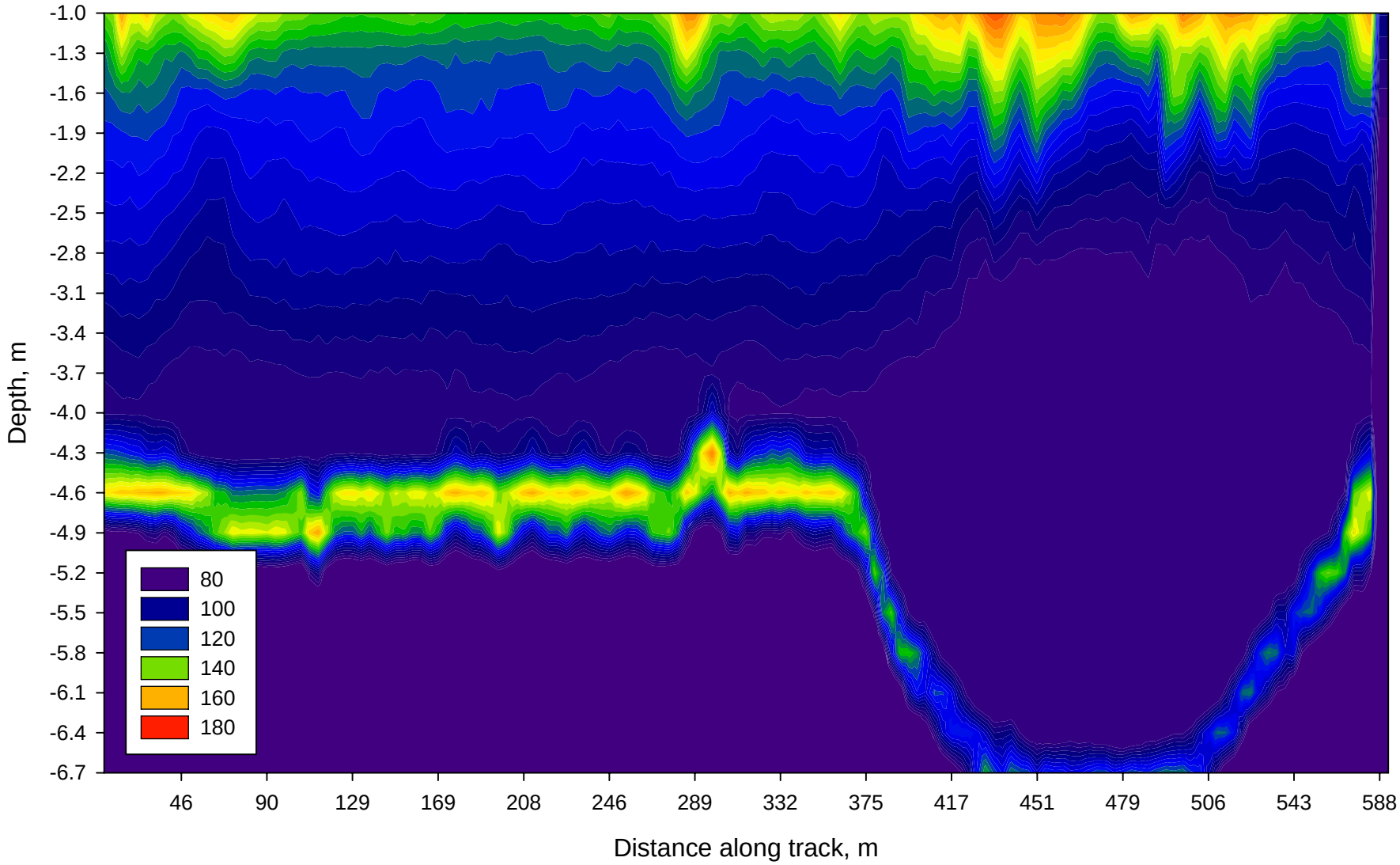
- In: 1039 EDT, 1439 UT
- Out: 1102EDT, 1502 UT
- Weather: sunny, wind < 10 kts
- Waves: no chop (in lee, protected)
- Depth: 8 feet
- Bottom: Mud

7. Just south of the U Mass Marine Operations Dock (congested area: Riverine drifter picked up - 1136 and moved 3 m to keep from fouling, then bumped - 1156 - into “Head of the Harbor” pump-out boat) 09

- In: 1121 EDT, 1521 UT
- Out: 1159 EDT, 1559 UT
- Weather: sunny, wind < 10 kts
- Waves: no chop (in lee, protected)
- Depth: varying shallow to deep in channels
- Bottom: very soft, very deep mud

TABLE 4.	Tables of Figures

E. of Spectacle Is. 19 July 2008 02, Signal Amplitude 20s ave.



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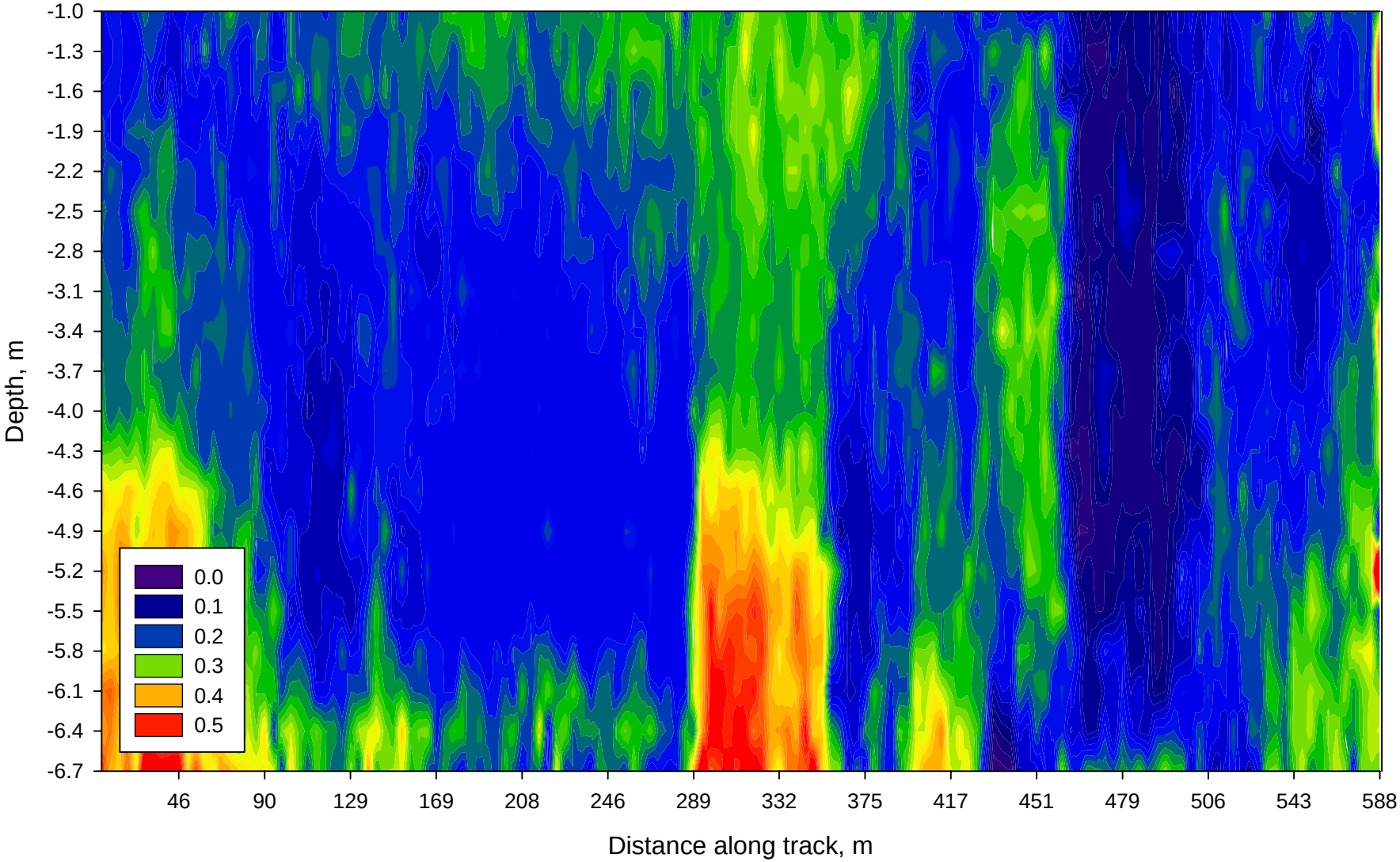

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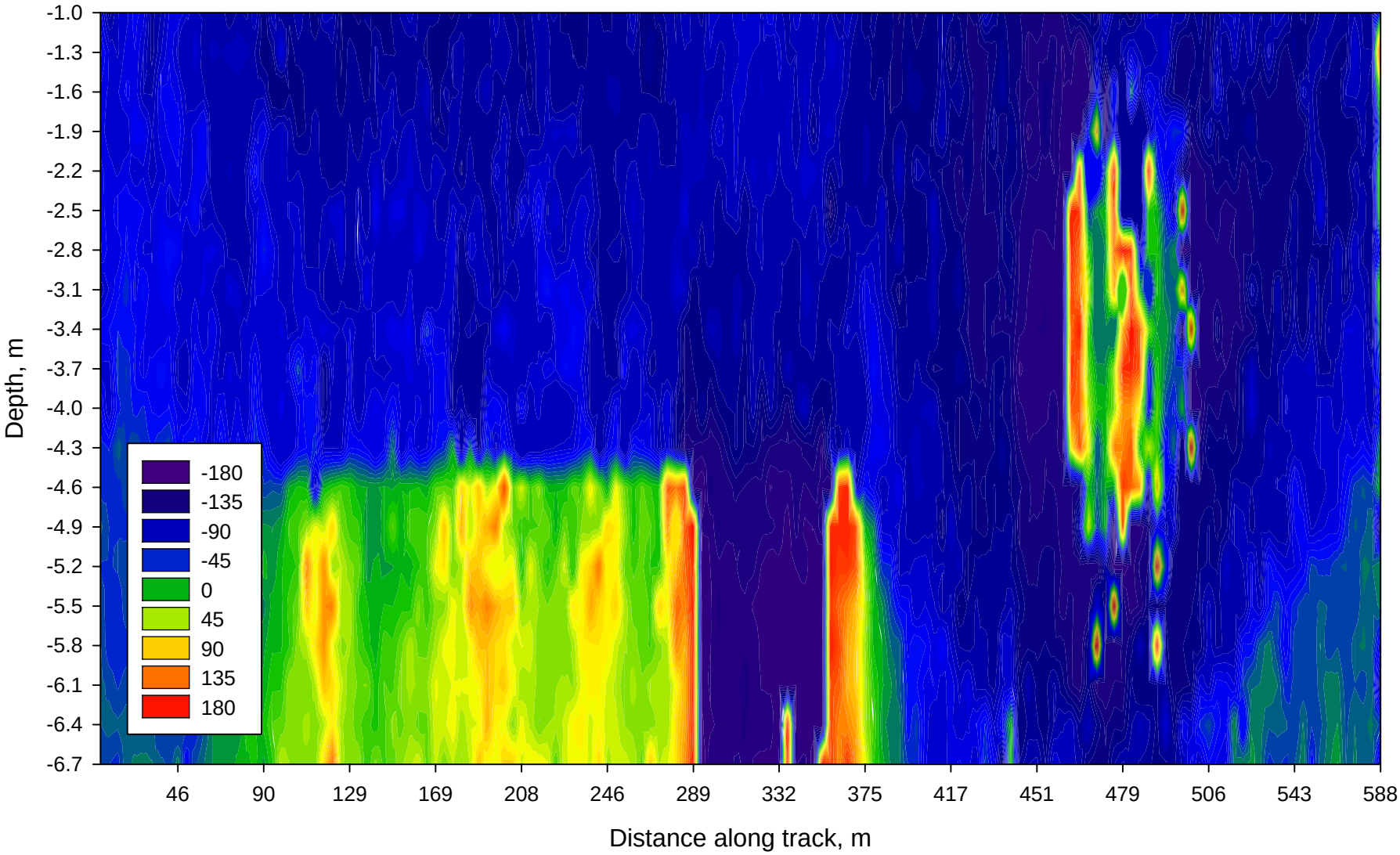
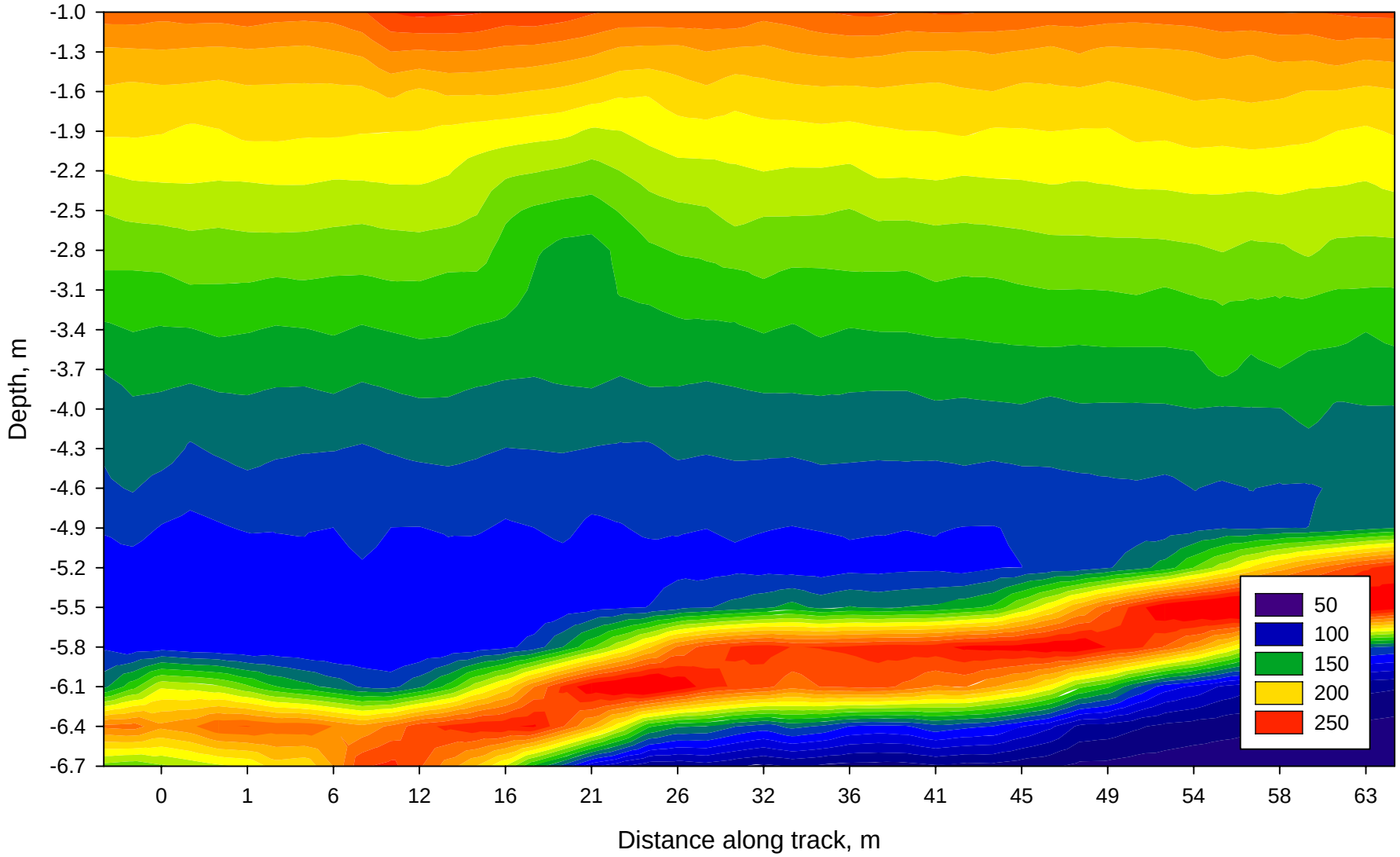
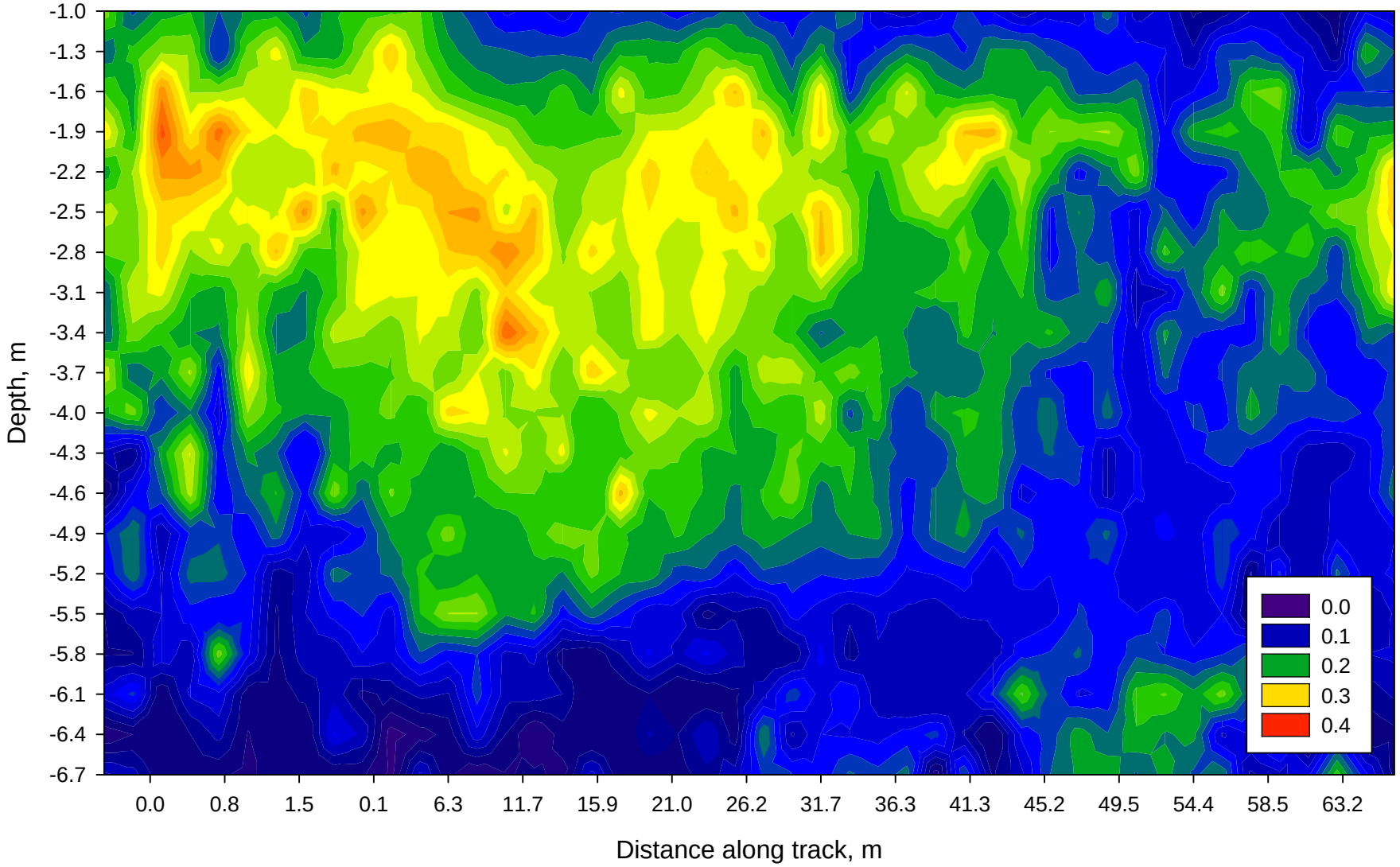


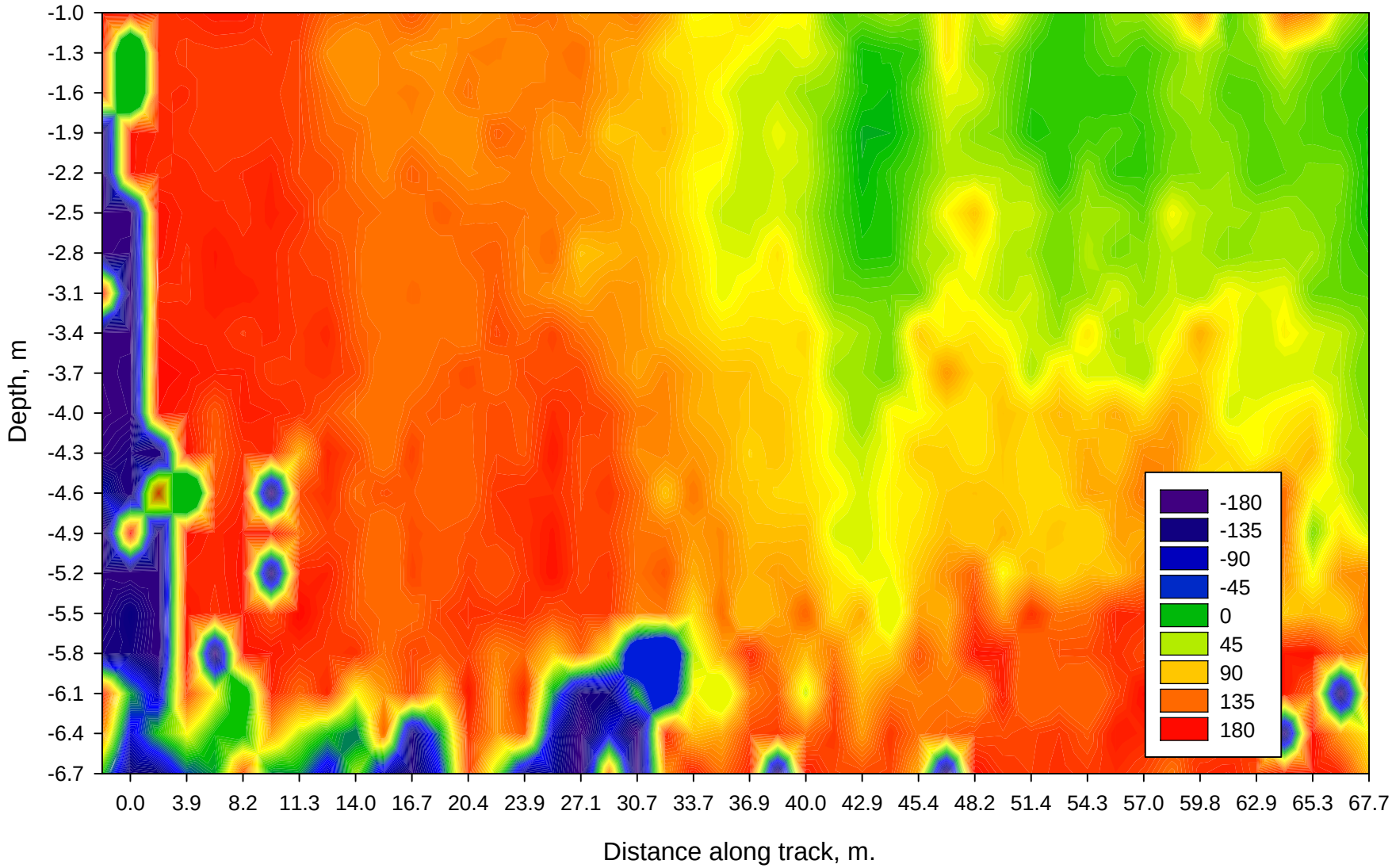
13 August 2008 Deployment 01 - Signal Amplitude, 20 s average
Main Shipping Channel

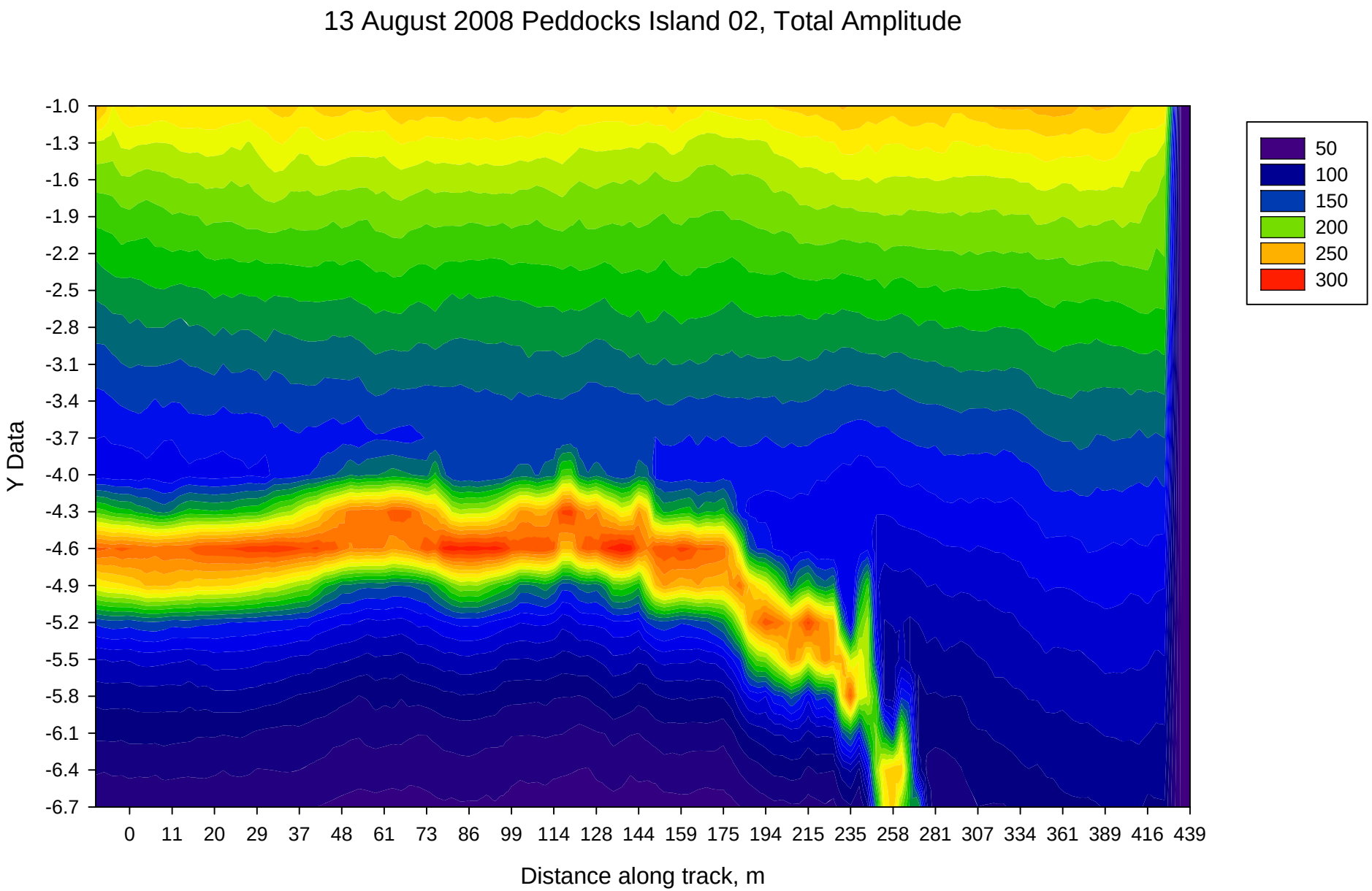


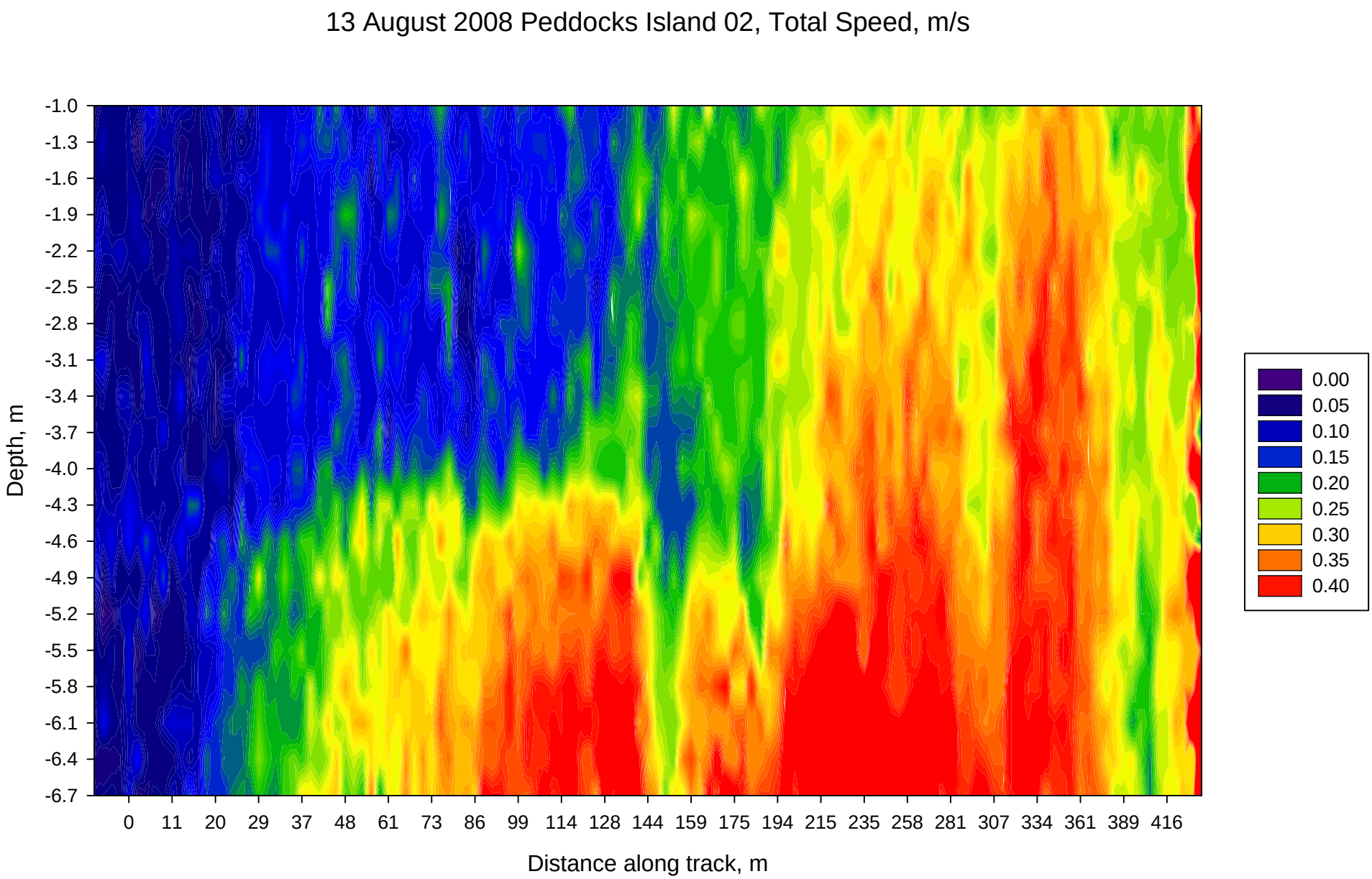
13 August 2008 Deployment 01 - Total Speed, m/s, 20 s average
Main Shipping Channel

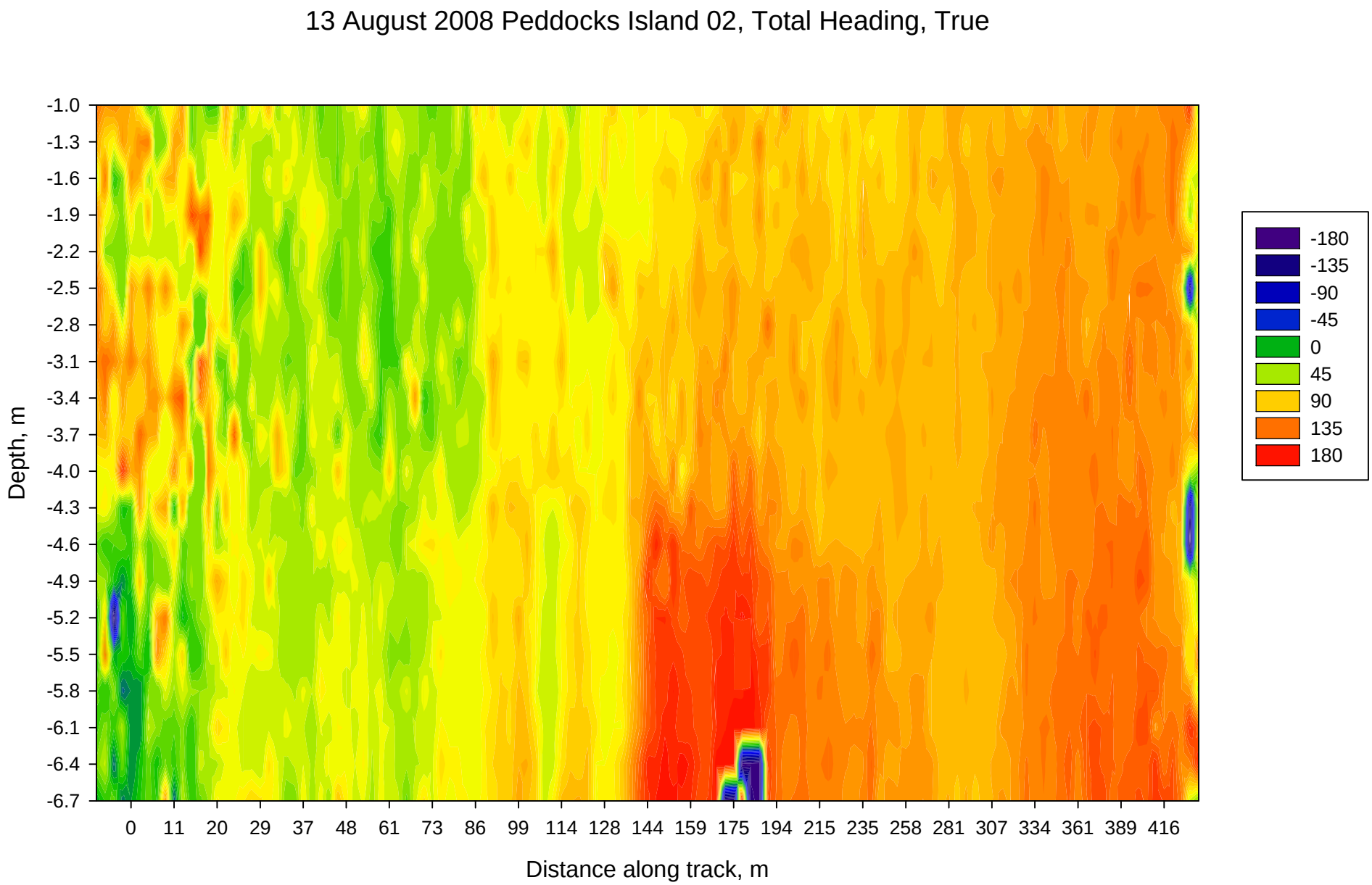


13 August 2008 Deployment 01 - Total Heading, 20 s average
Main Shipping Channel



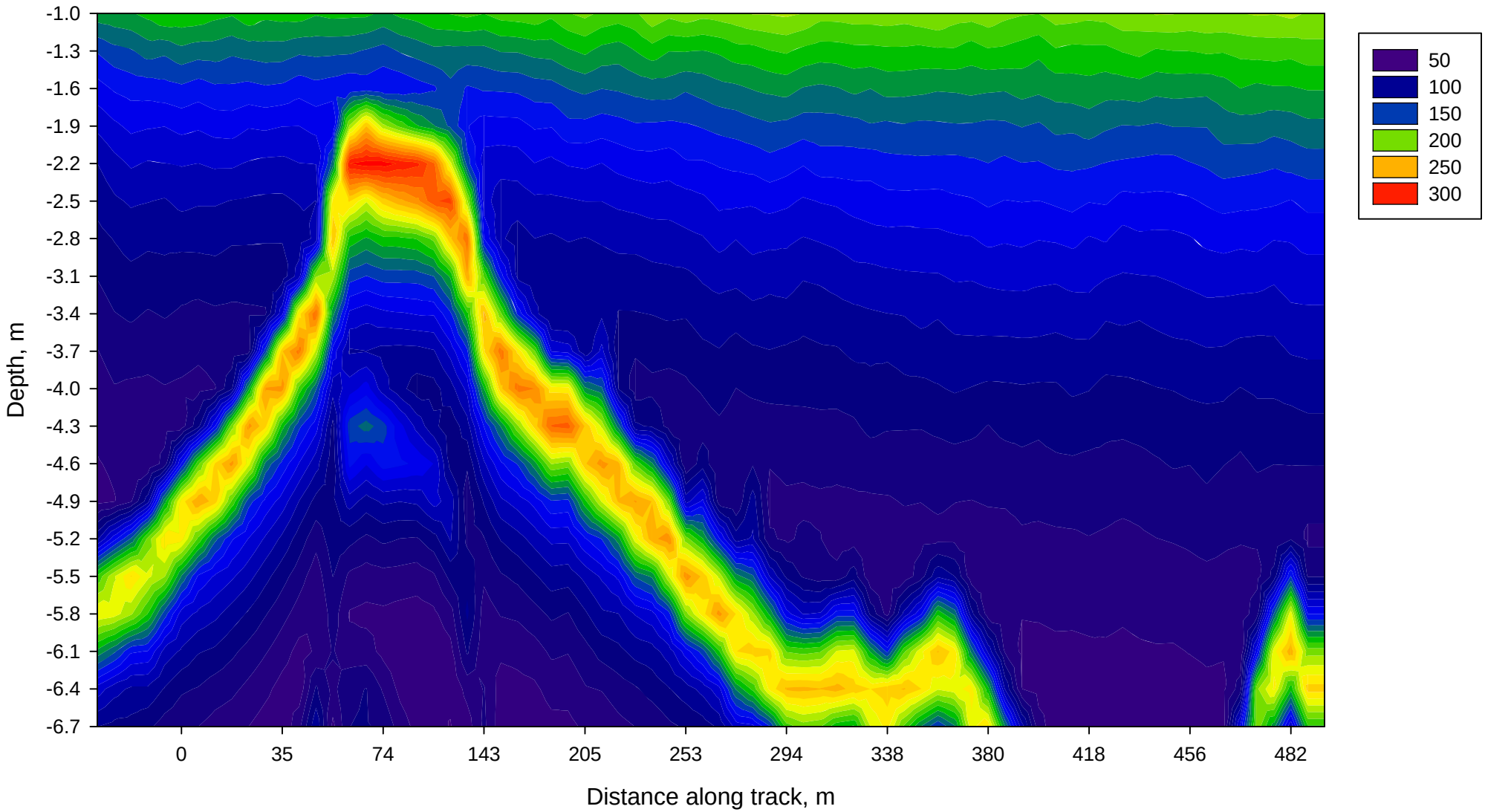

13 August 2008 Peddocks Island 02, Total Amplitude
Y Data
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
0 11 20 29 37 48 61 73 86 99 114 128 144 159 175 194 215 235 258 281 307 334 361 389 416 439
Distance along track, m
50
100
150
200
250
300

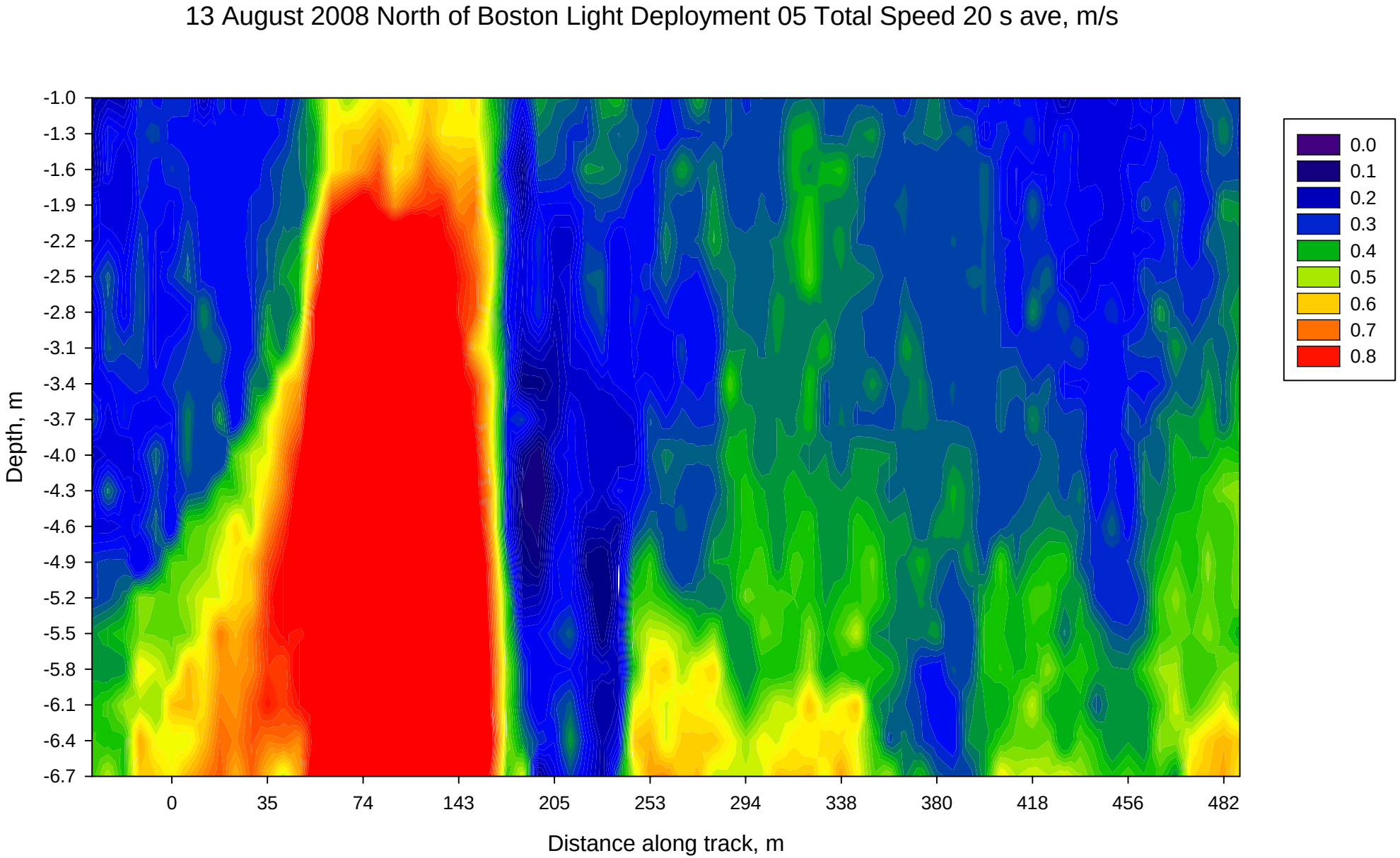

13 August 2008 Peddocks Island 02, Total Speed, m/s
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
0 11 20 29 37 48 61 73 86 99 114 128 144 159 175 194 215 235 258 281 307 334 361 389 416
Distance along track, m
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

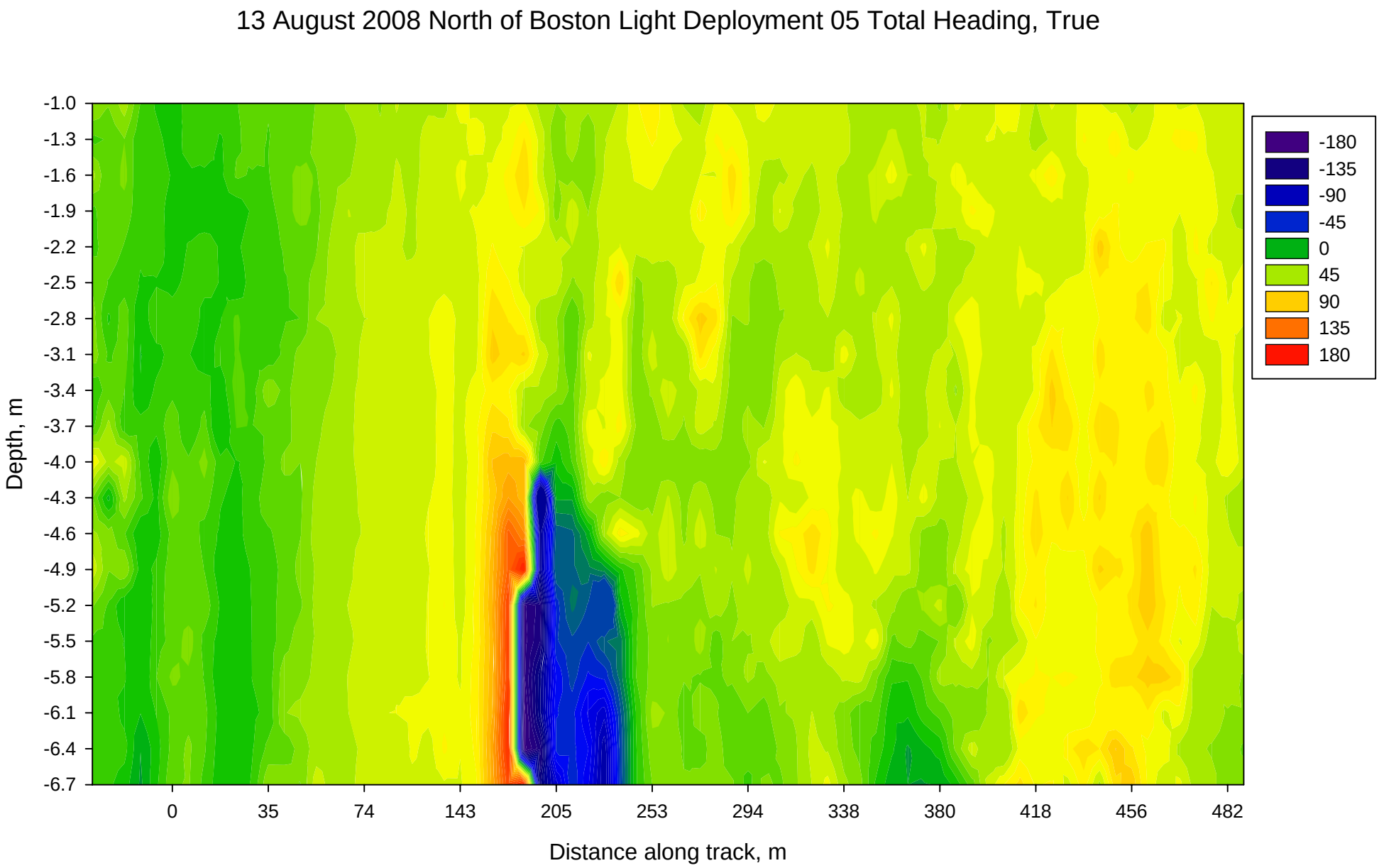

13 August 2008 Peddocks Island 02, Total Heading, True
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
0
11
20
29
37
48
61
73
86
99
114
128
144
159
175
194
215
235
258
281
307
334
361
389
416
Distance along track, m
-180
-135
-90
-45
0
45
90
135
180


Little Brewster Island
© 2008 Europa Technologies
© 2008 Tele Atlas
©2008 Google
42°19'47.47" N 70°53'33.92" W
elev 0 ft
Jul 29, 2007
Eye alt 1983 ft

13 August 2008 North of Boston Light Deployment 05 Amplitude

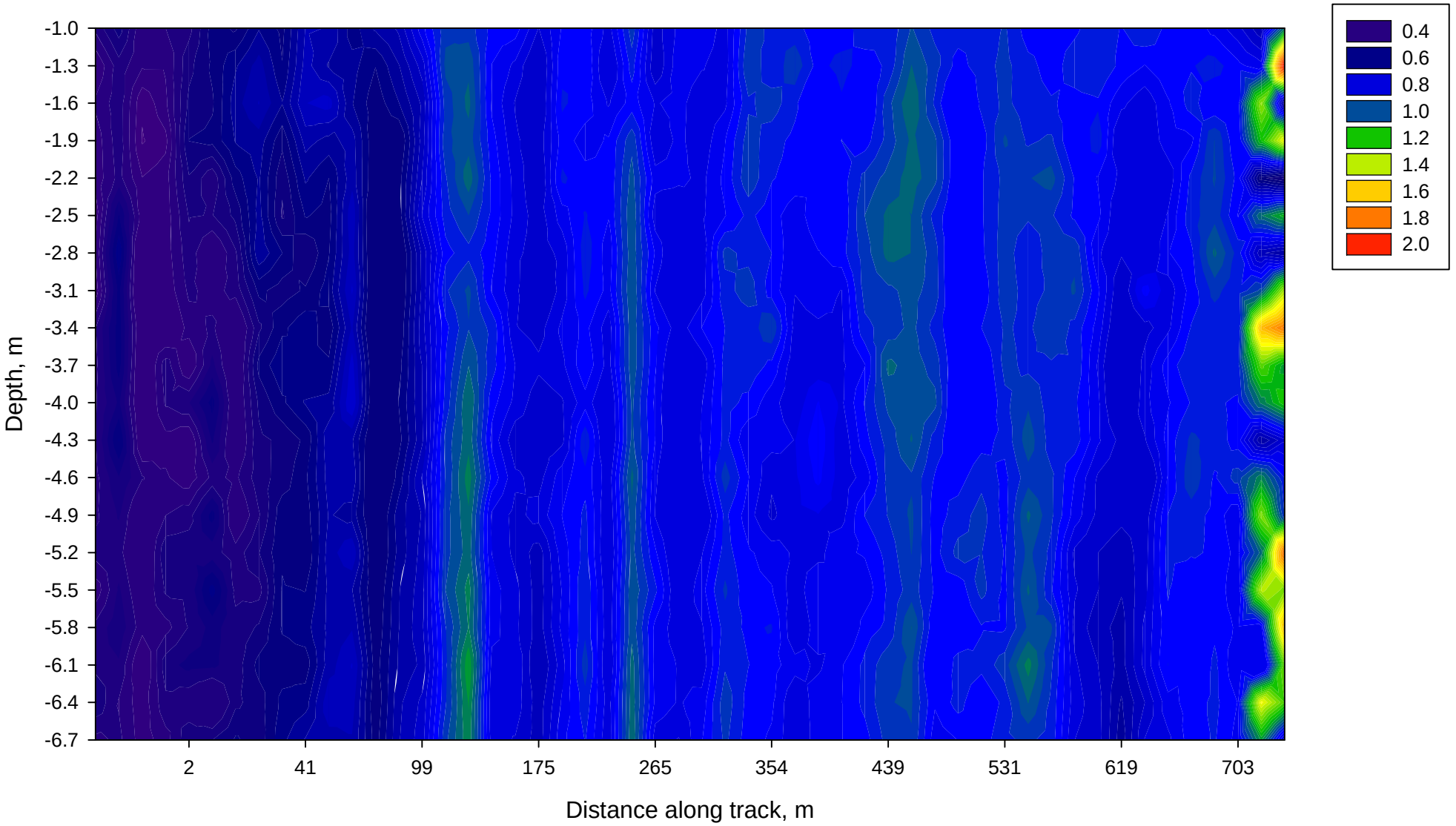



13 August 2008 North of Boston Light Deployment 05 Total Speed 20 s ave, m/s
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
0
35
74
143
205
253
294
338
380
418
456
482
Distance along track, m
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

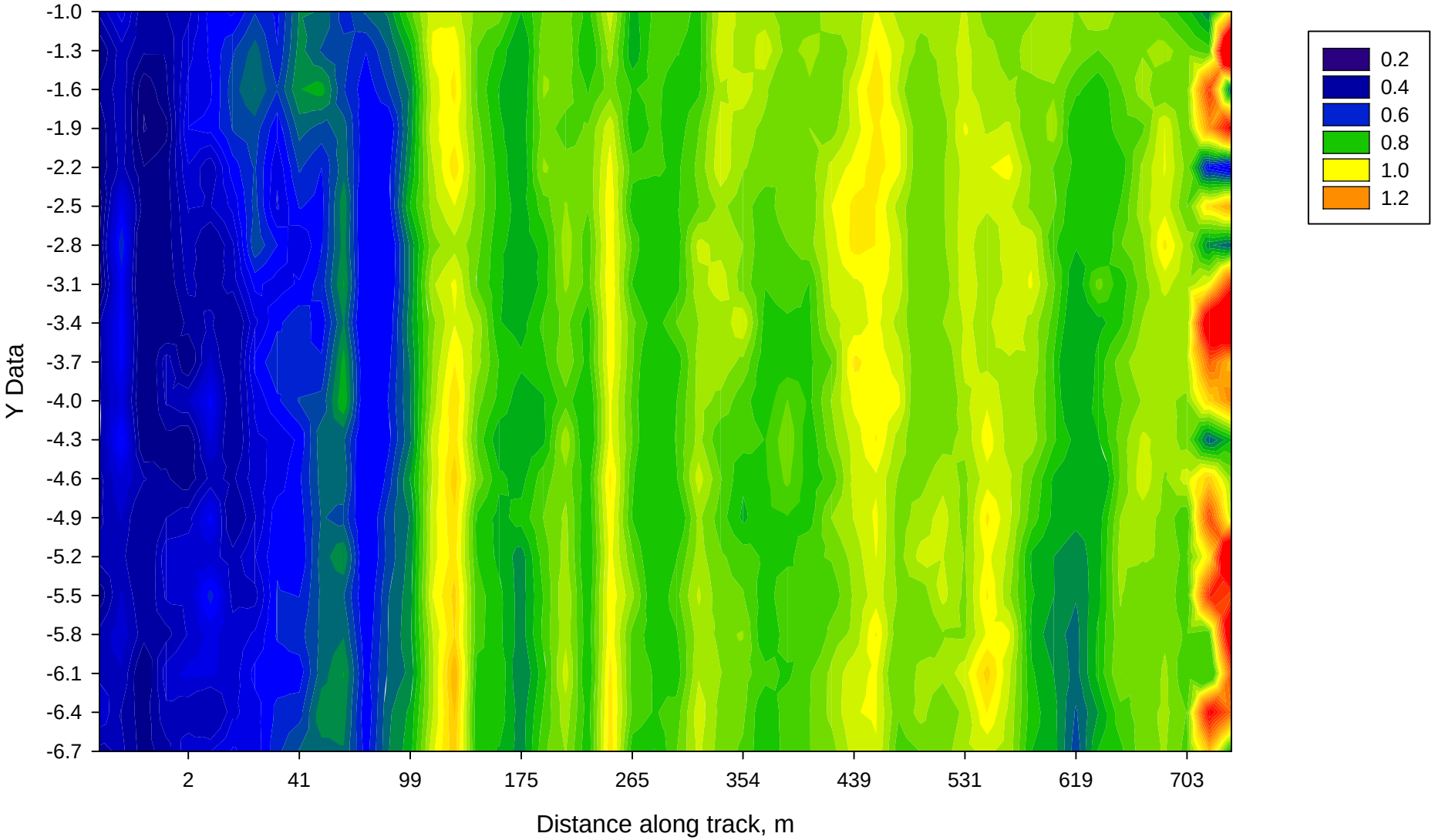

13 August 2008 North of Boston Light Deployment 05 Total Heading, True
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
0
35
74
143
205
253
294
338
380
418
456
482
Distance along track, m
-180
-135
-90
-45
0
45
90
135
180

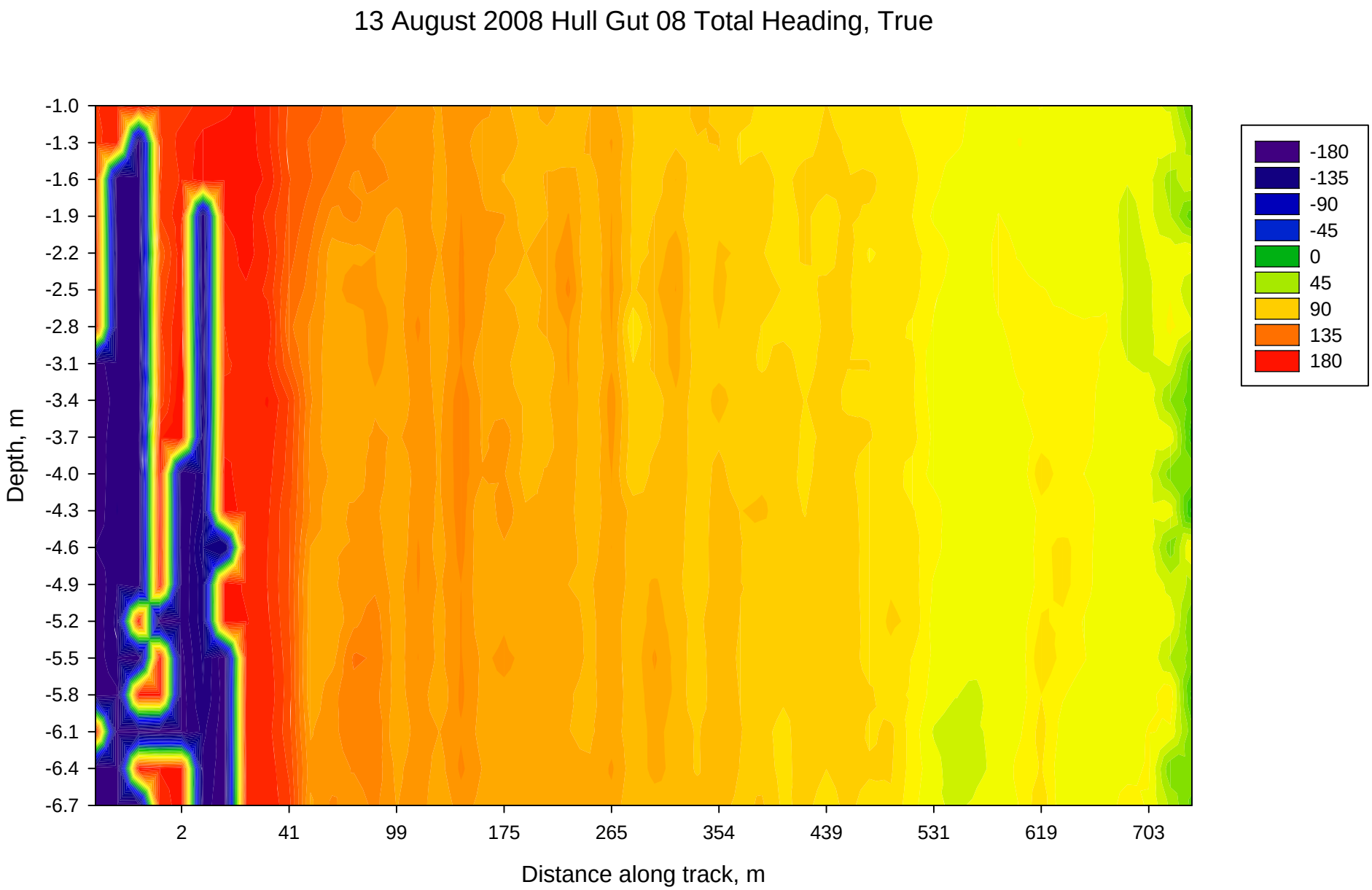

© 2008 Tele Atlas
©2008 Google
42°18'19.32" N 70°55'22.83" W
elev 0 ft
Jul 29, 2007
Eye alt 2668 ft

13 August 2008 Hull Gut 08 Total Amplitude, 20 sec. ave.

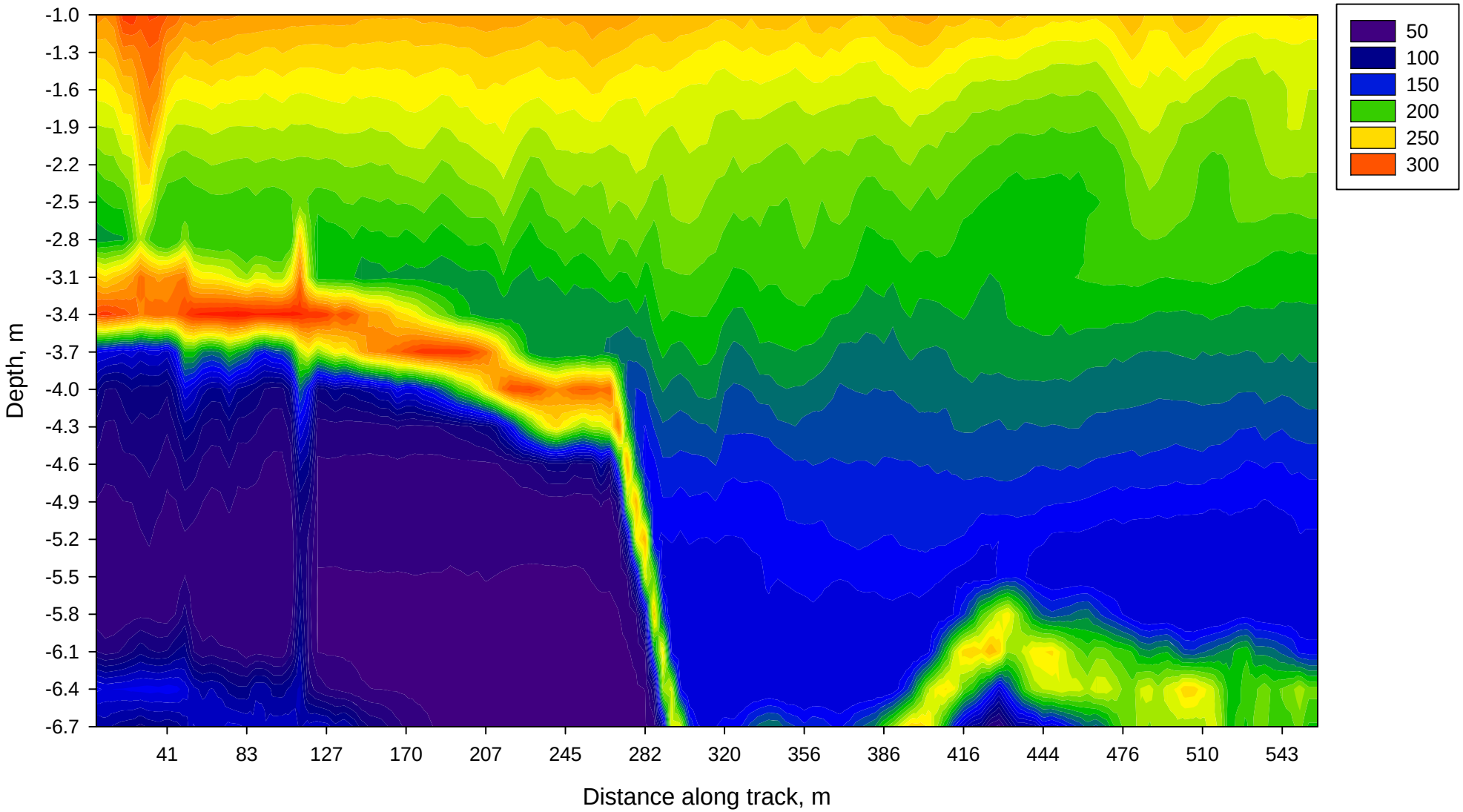


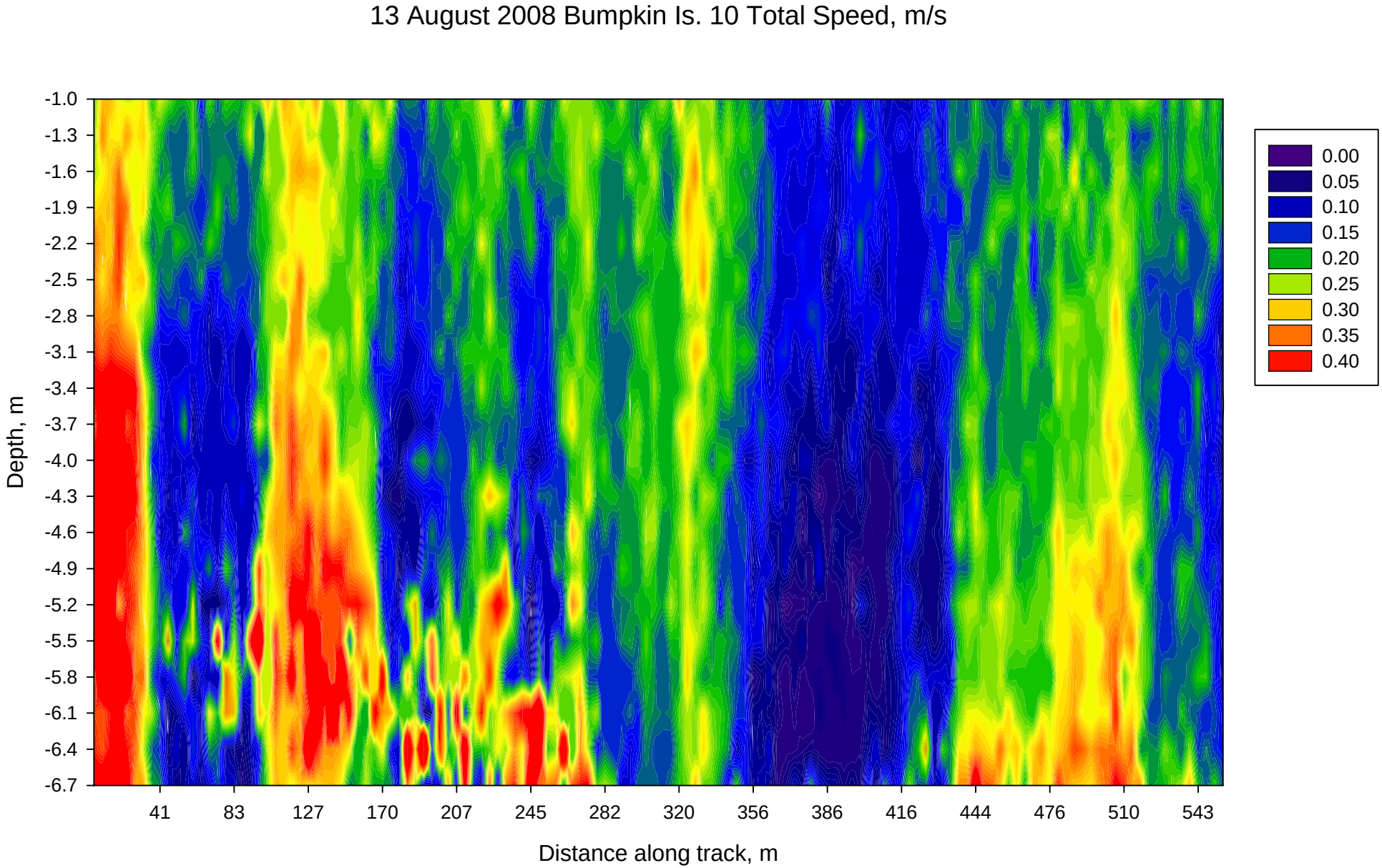
13 August 2008 Hull Gut 08 Total Speed, m/s

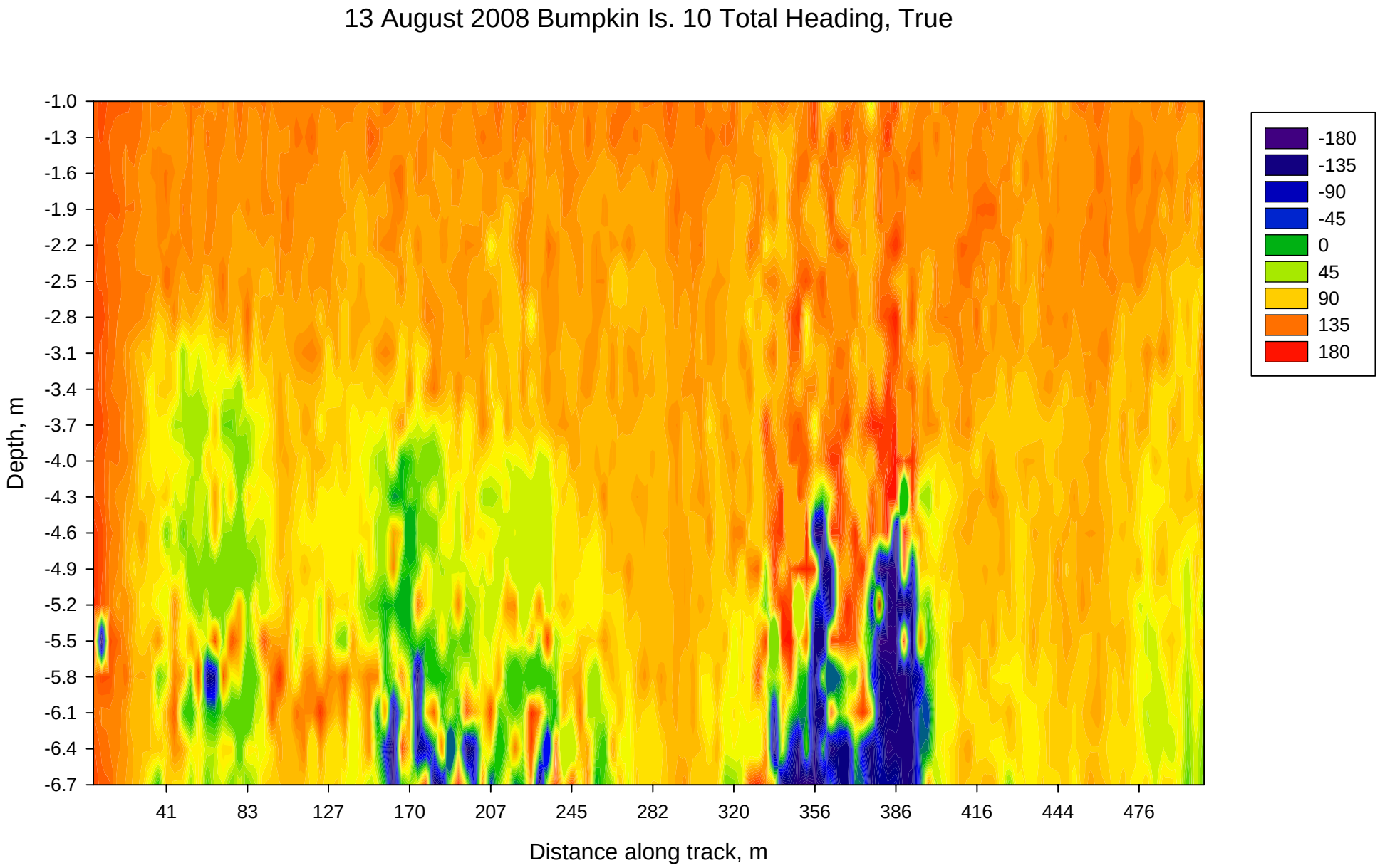



13 August 2008 Hull Gut 08 Total Heading, True
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
2
41
99
175
265
354
439
531
619
703
Distance along track, m
-180
-135
-90
-45
0
45
90
135
180

13 August 2008 Bumpkin Is. 10 Total Amplitude




13 August 2008 Bumpkin Is. 10 Total Speed, m/s
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
41
83
127
170
207
245
282
320
356
386
416
444
476
510
543
Distance along track, m
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40


13 August 2008 Bumpkin Is. 10 Total Heading, True
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
41
83
127
170
207
245
282
320
356
386
416
444
476
Distance along track, m
-180
-135
-90
-45
0
45
90
135
180


2
Little Brewster Island
© 2008 Europa Technologies
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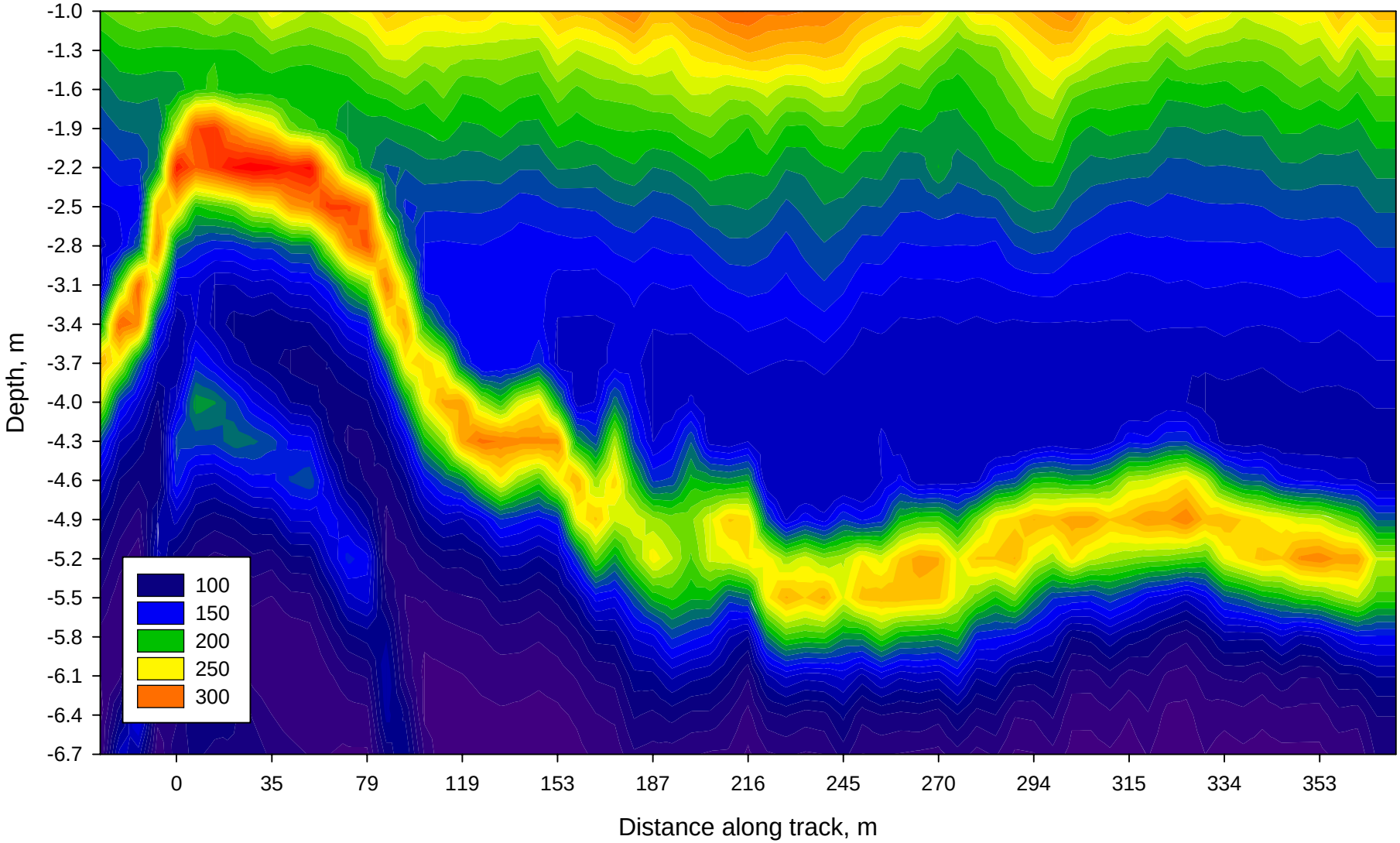
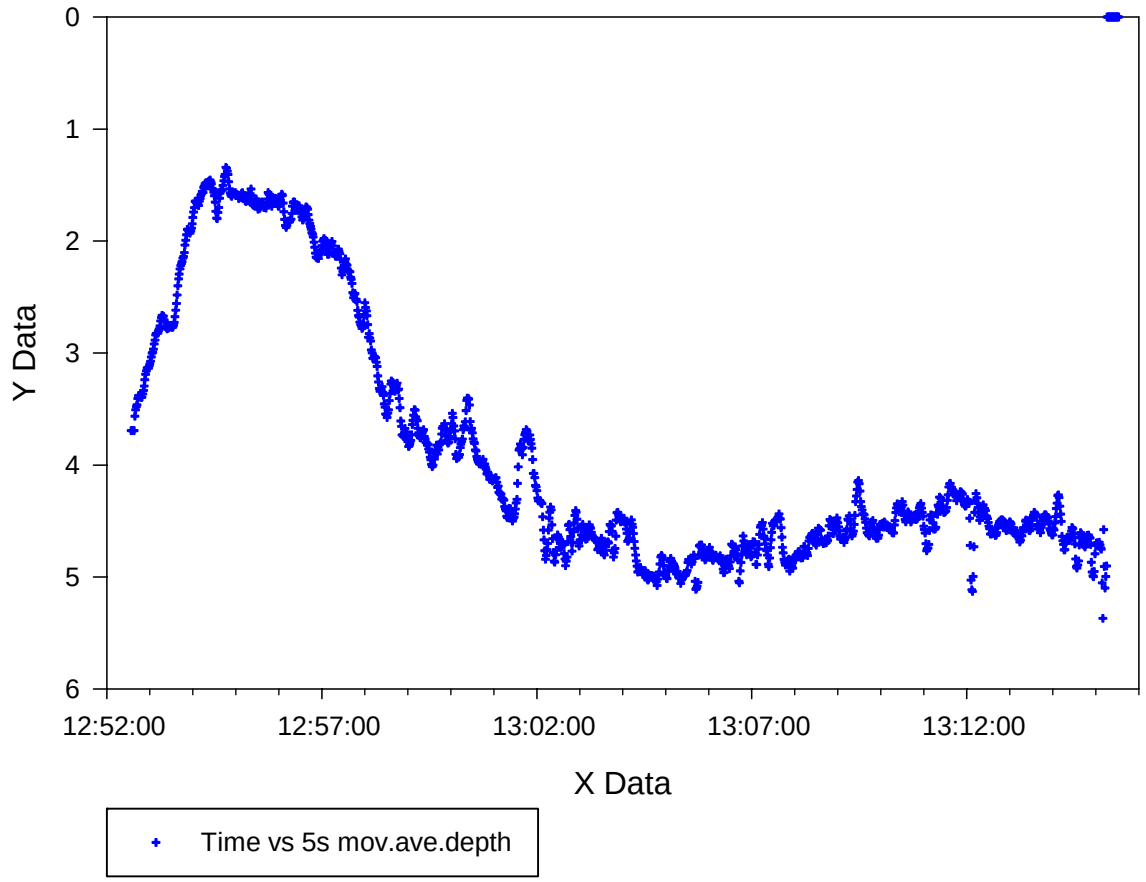
©2008 Google
42°19'45.12" N 70°53'34.06" W
elev 0 ft
Jul 29, 2007
Eye alt 1891 ft

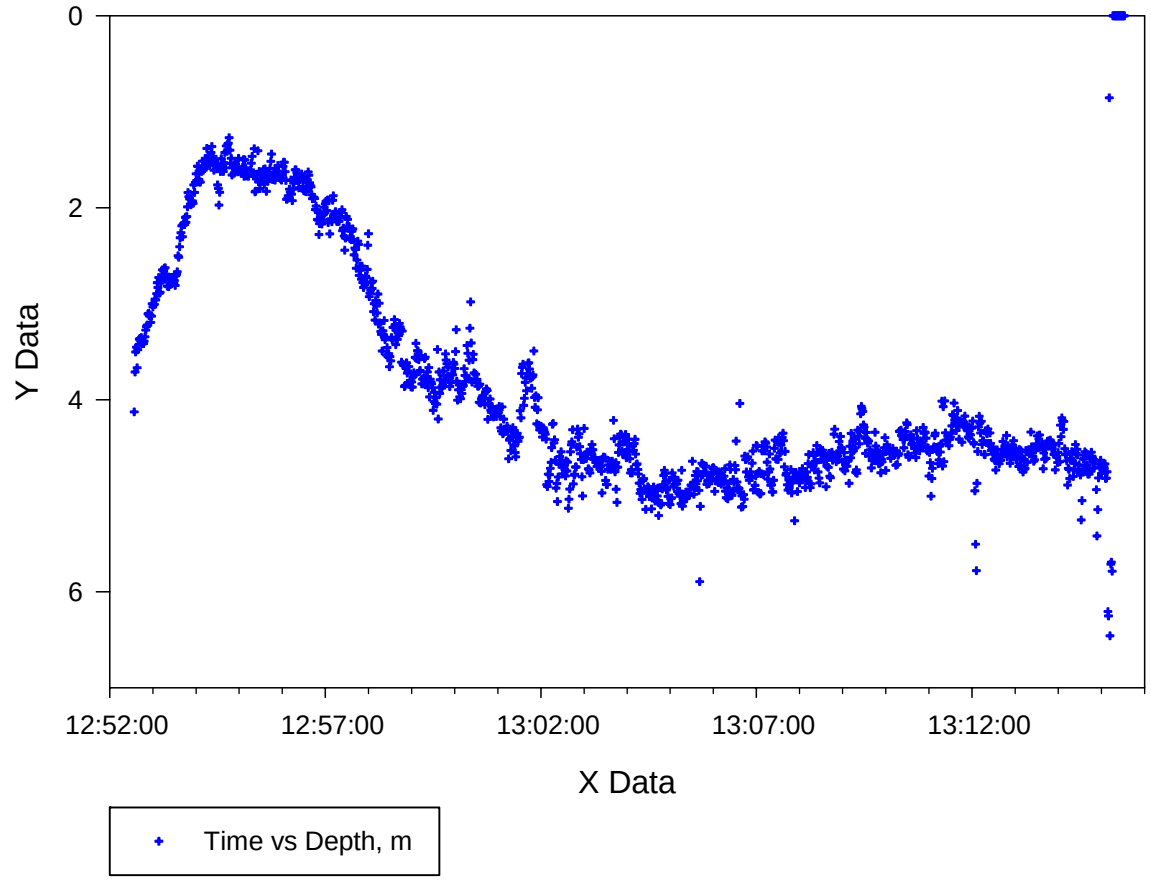
10 September 2008 West of Little Brewster 05 - Total Amplitude, 20 s. ave.



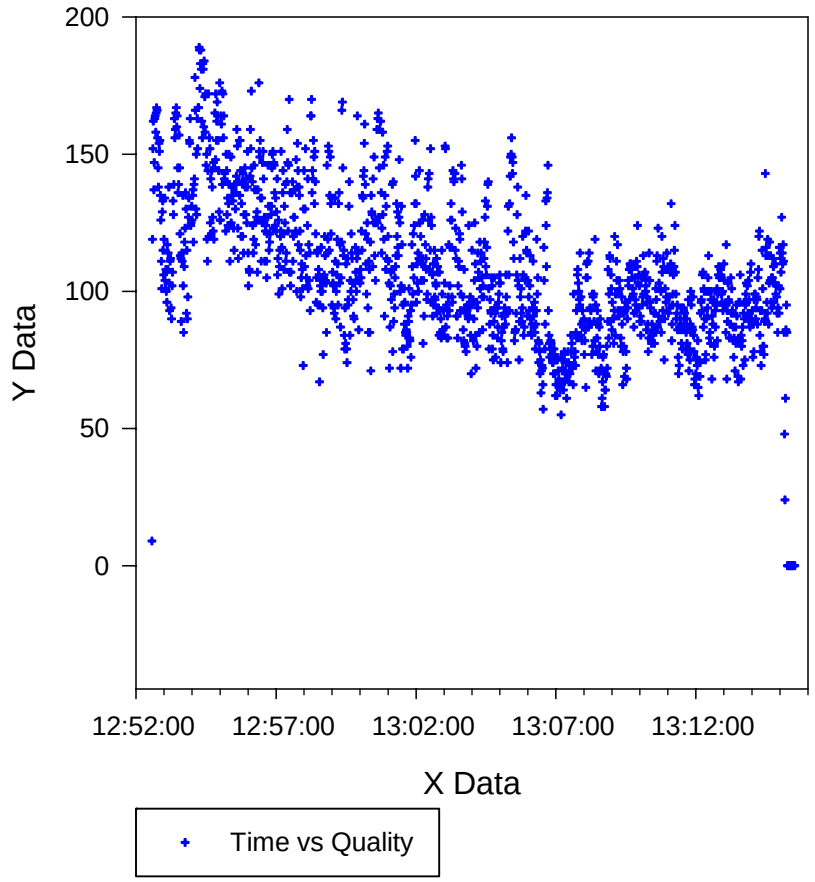
10 September 2008 West of Little Brewster 05 - Depth 5s ave., m



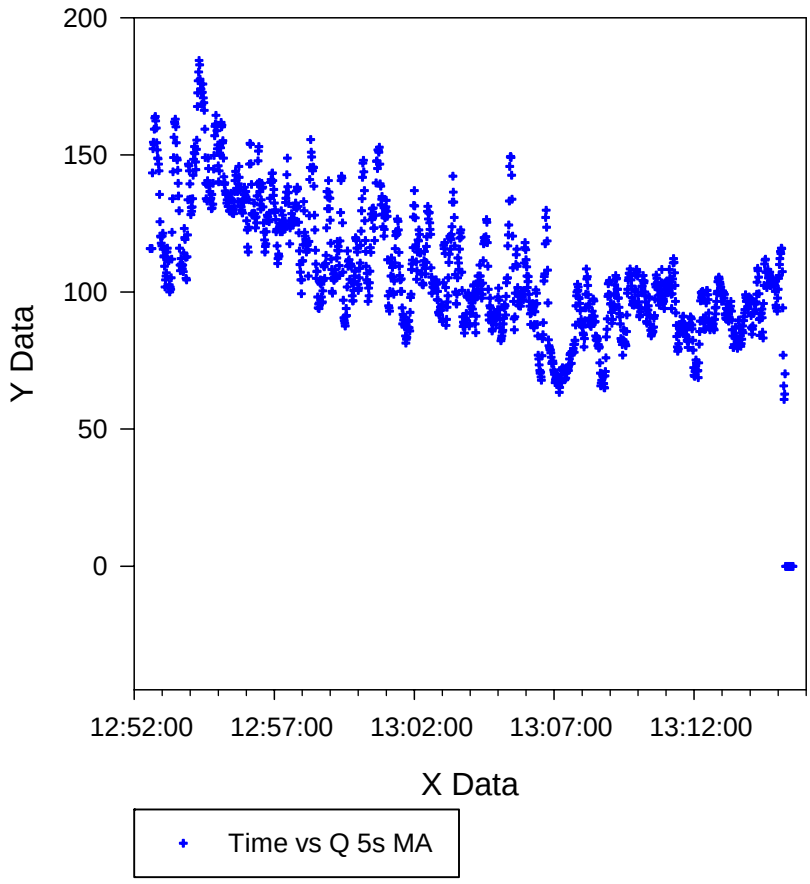
10 September 2008 West of Little Brewster 05 - Depth, m



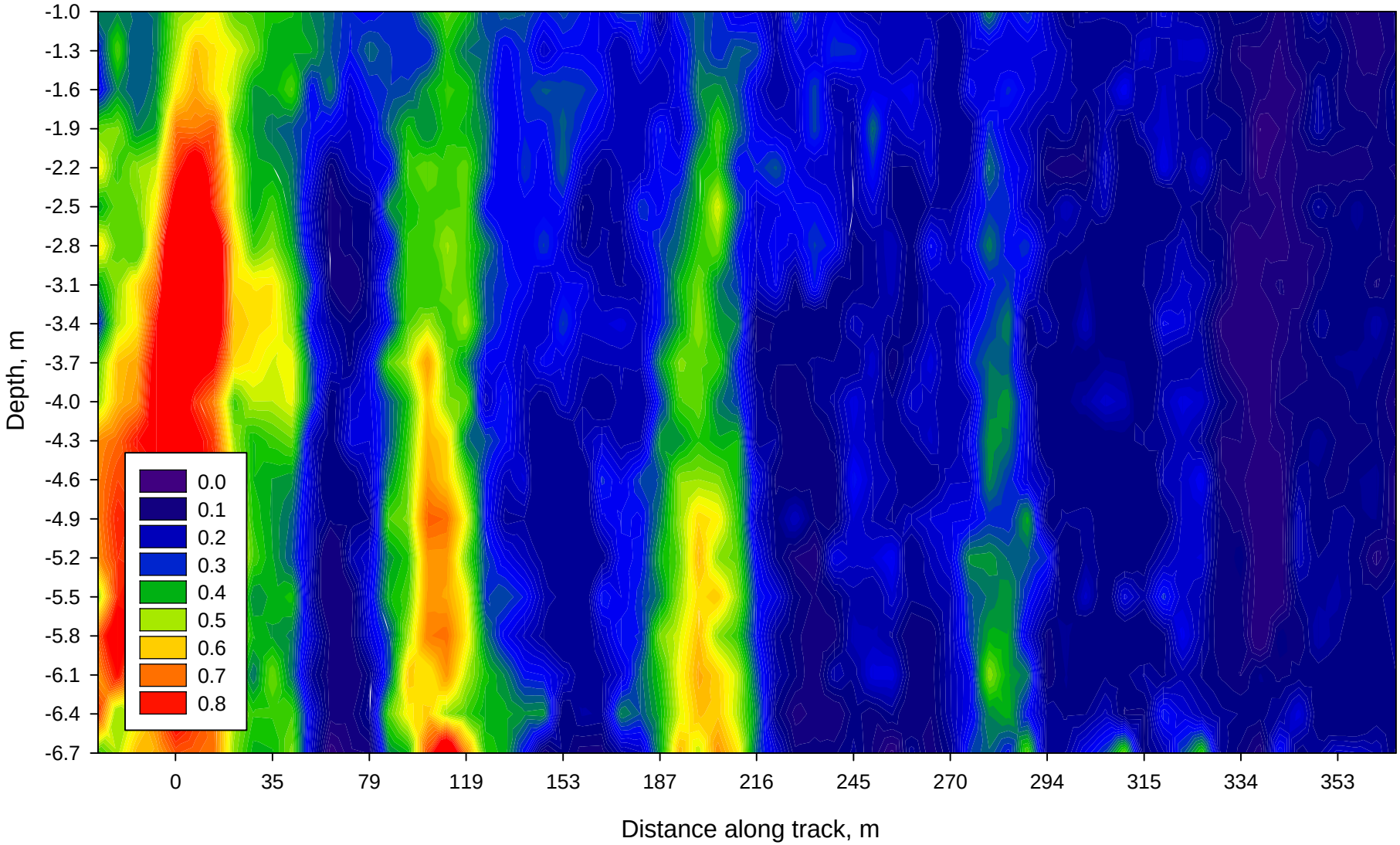
10 September 2008 West of Little Brewster 05 - Quality

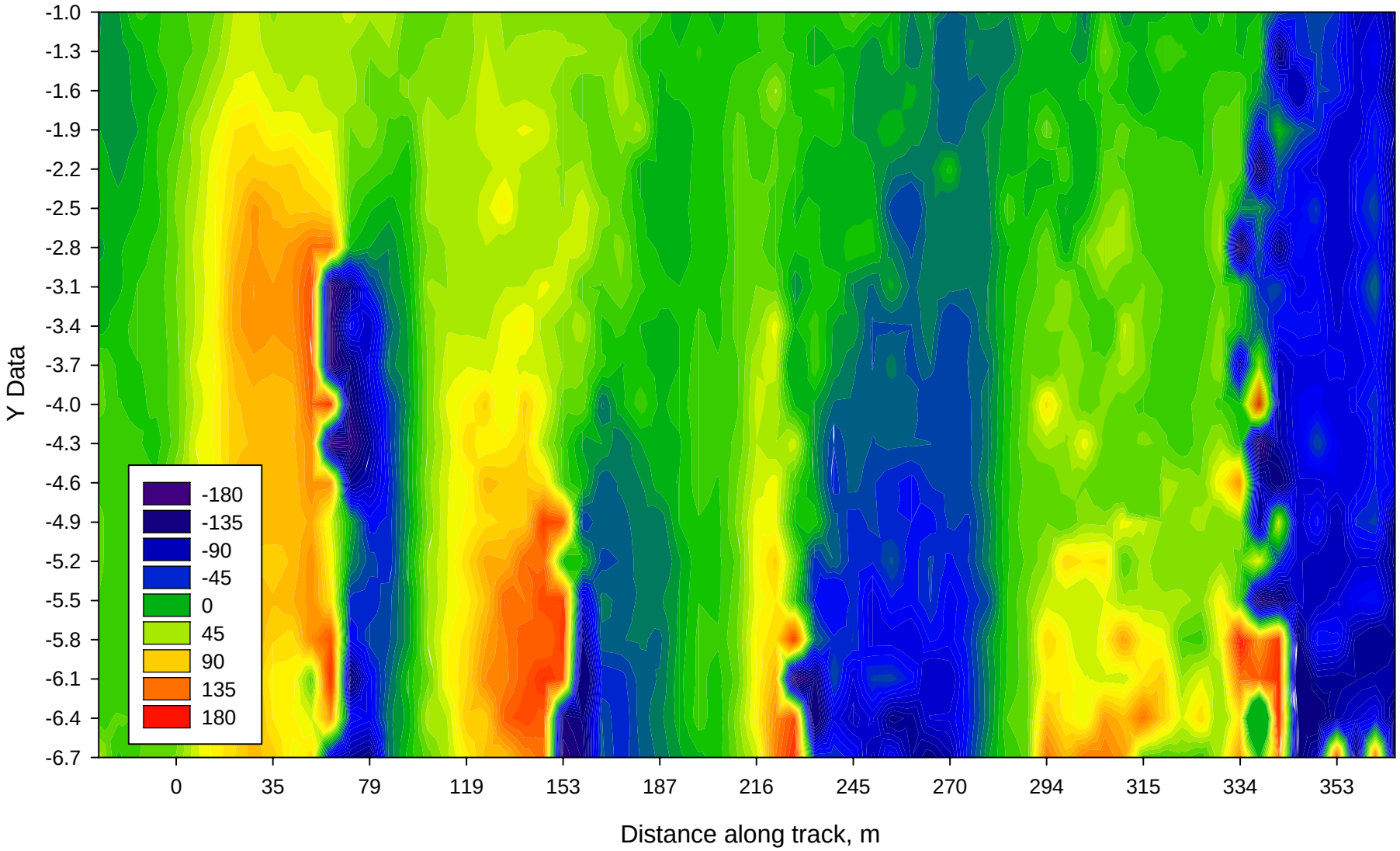


10 September 2008 West of Little Brewster 05 - Quality, 5 s. ave.

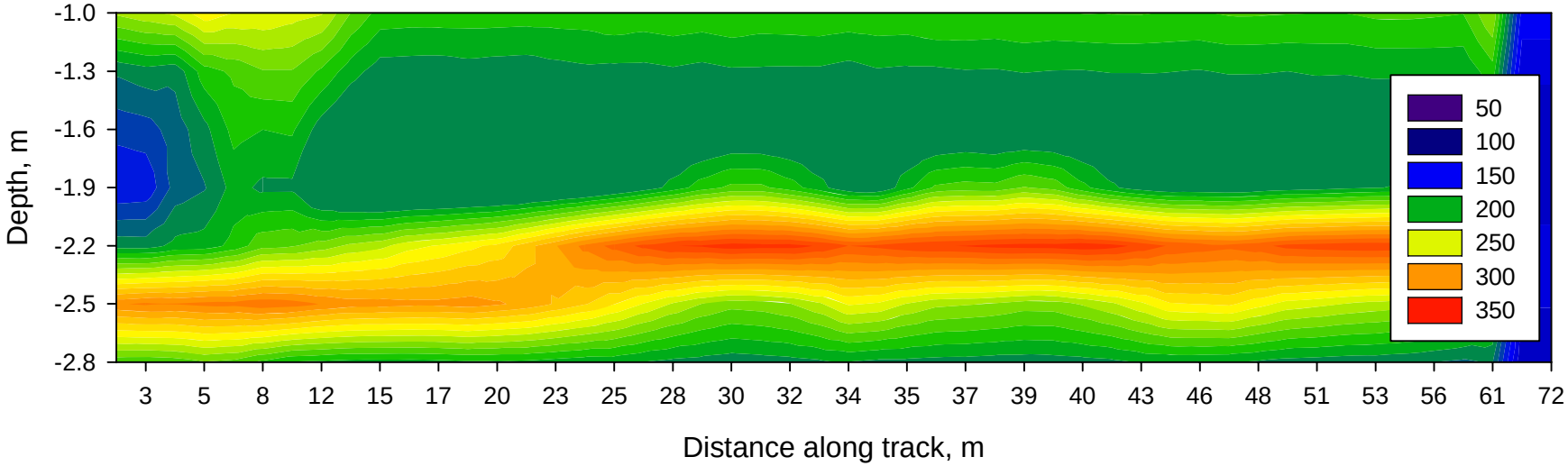


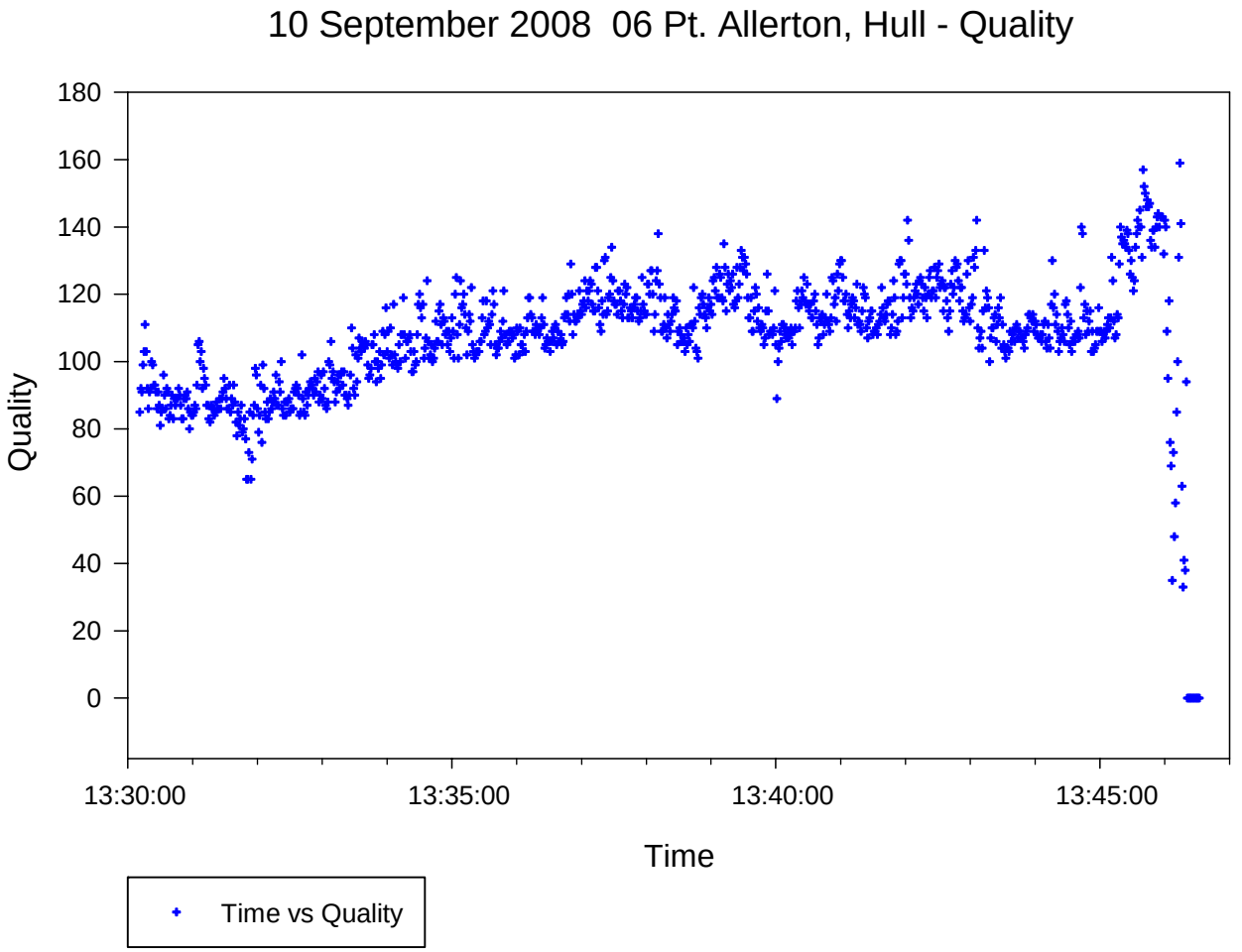
10 September 2008 West of Little Brewster 05 - Total Speed 20s ave., m/s 05

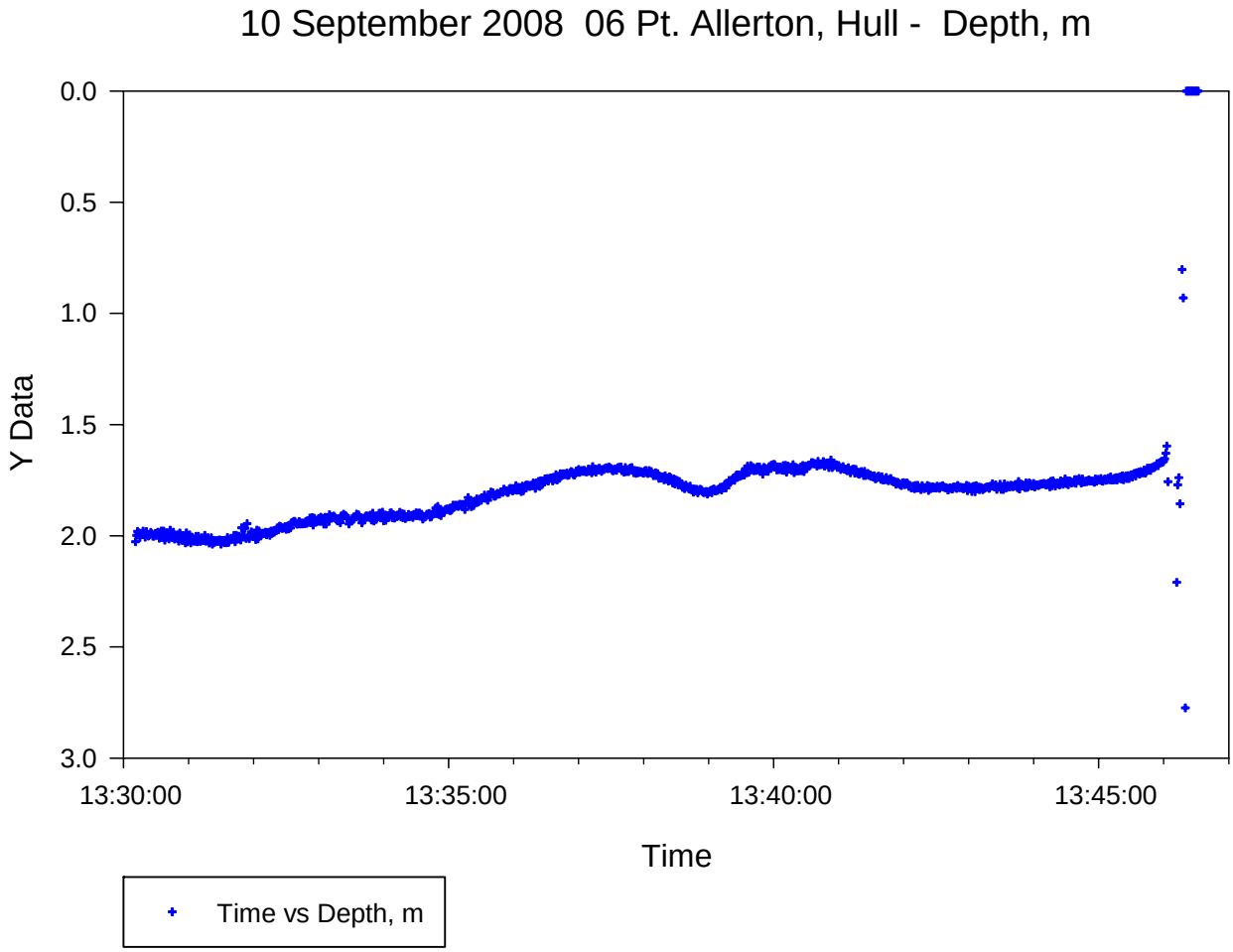


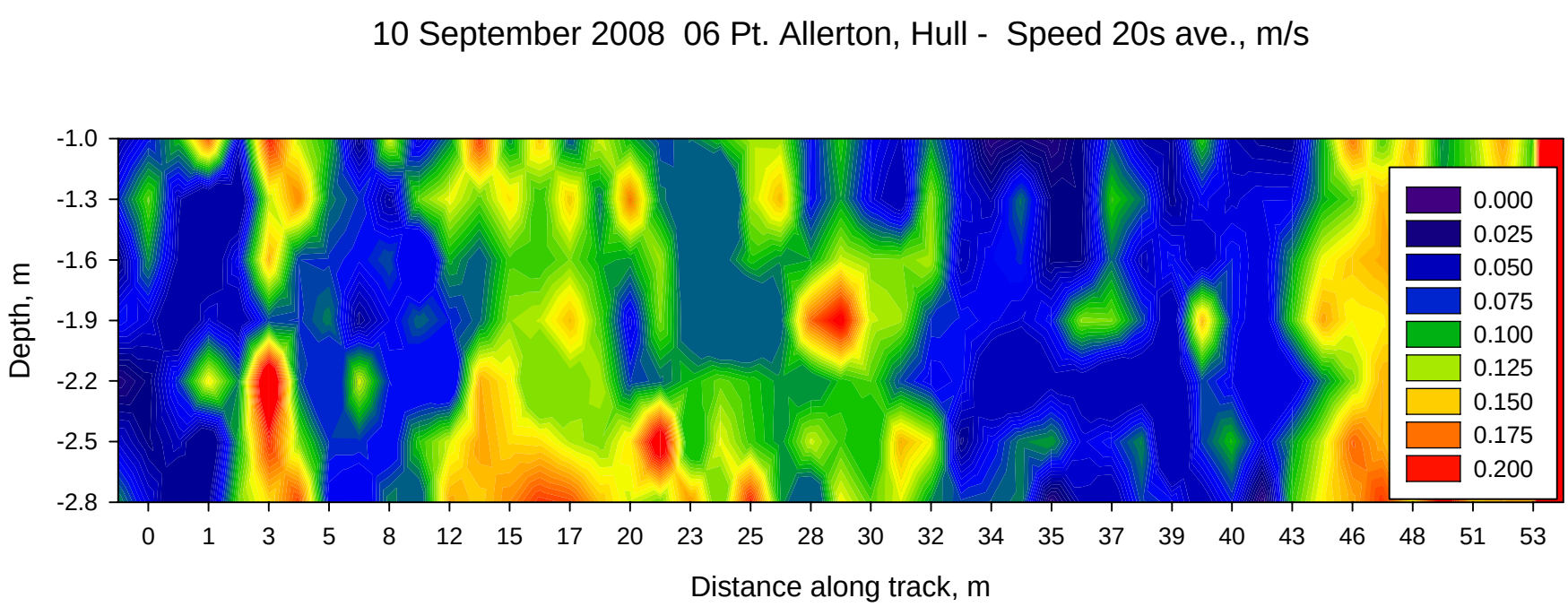

10 September 2008 West of Little Brewster 05 - Total Heading 20 s. ave., m/s
Y Data
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
-3.1
-3.4
-3.7
-4.0
-4.3
-4.6
-4.9
-5.2
-5.5
-5.8
-6.1
-6.4
-6.7
-180
-135
-90
-45
0
45
90
135
180
0
35
79
119
153
187
216
245
270
294
315
334
353
Distance along track, m

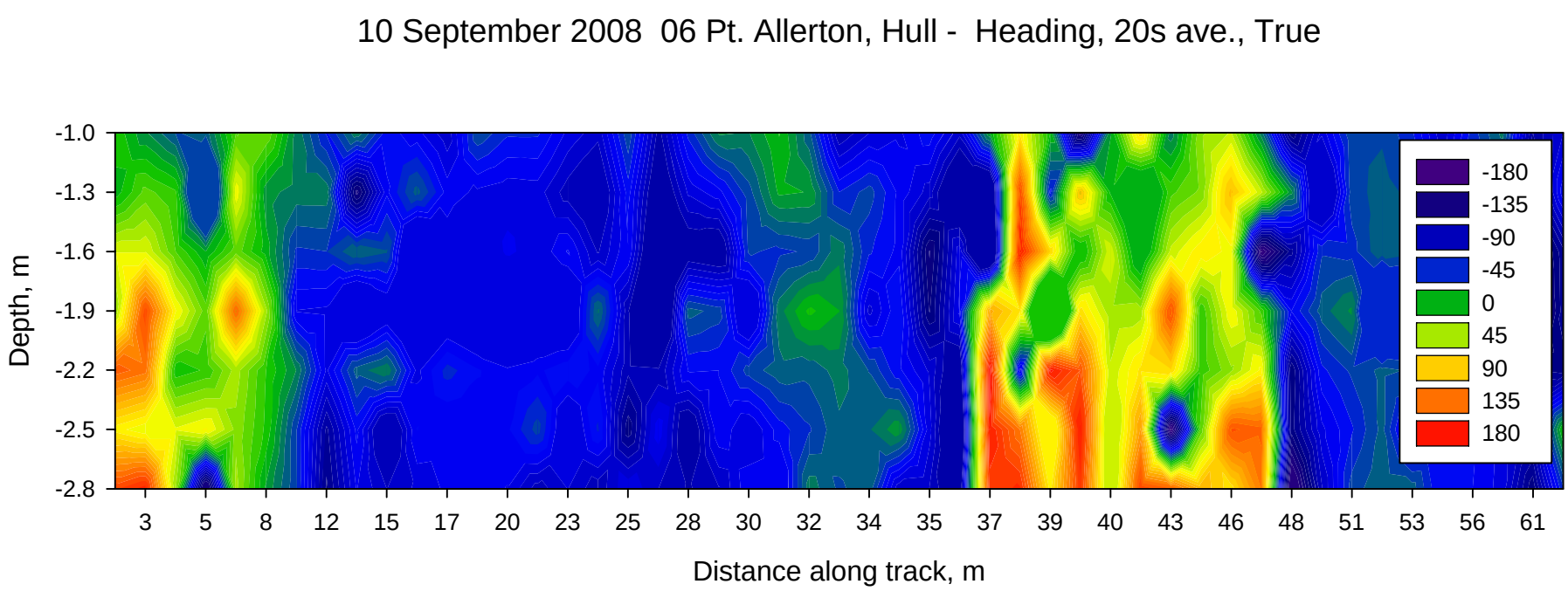
10 September 2008 06 Pt. Allerton, Hull - Amplitude 20s ave.



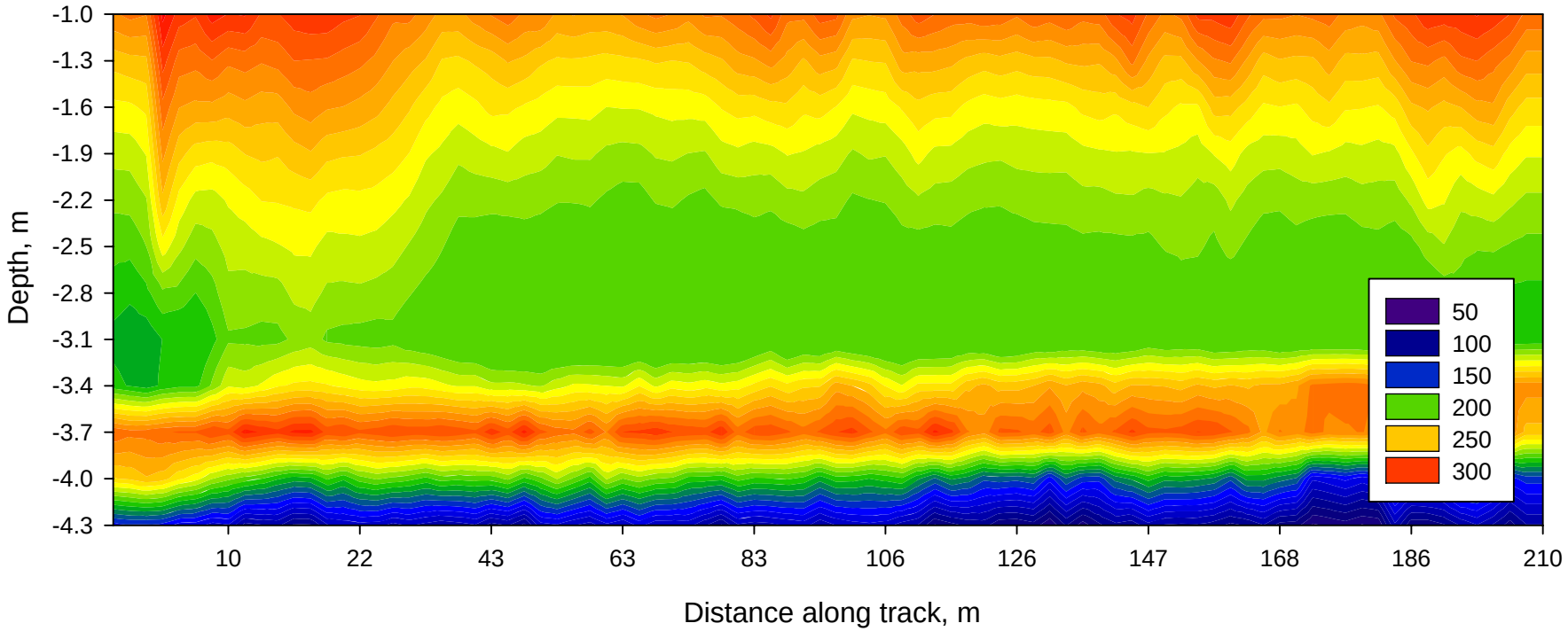

10 September 2008 06 Pt. Allerton, Hull - Quality
Quality
180
160
140
120
100
80
60
40
20
0
13:30:00
13:35:00
13:40:00
13:45:00
Time
Time vs Quality


10 September 2008 06 Pt. Allerton, Hull - Depth, m
Y Data
0.0
0.5
1.0
1.5
2.0
2.5
3.0
13:30:00
13:35:00
13:40:00
13:45:00
Time
Time vs Depth, m

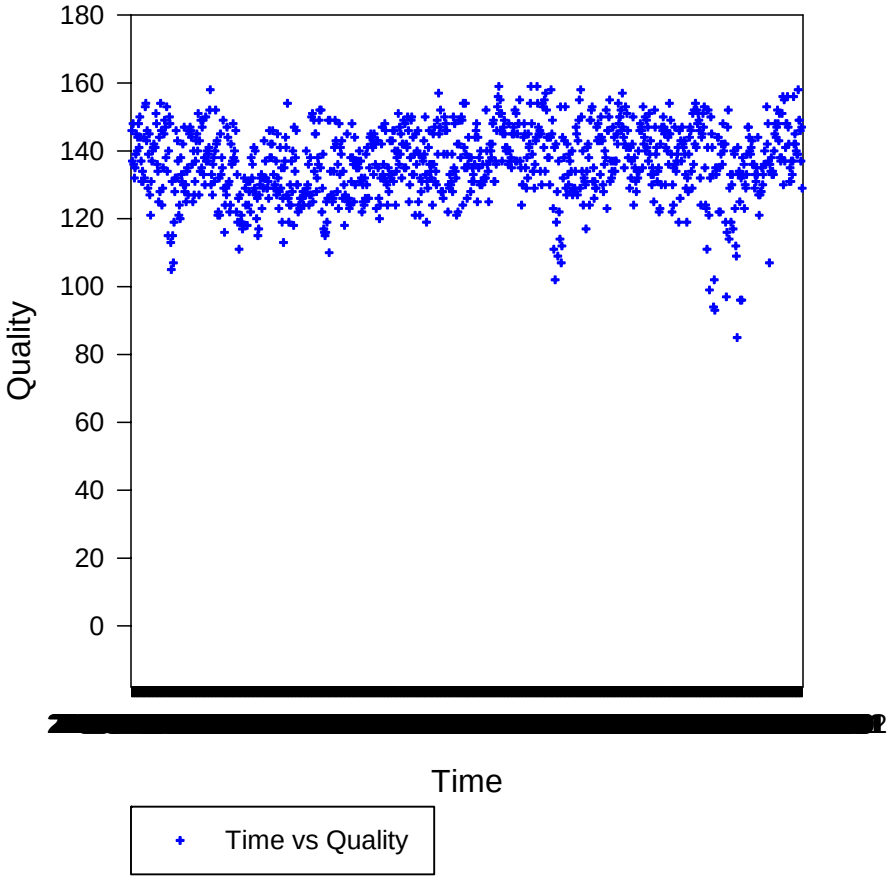

10 September 2008 06 Pt. Allerton, Hull - Speed 20s ave., m/s
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
0
1
3
5
8
12
15
17
20
23
25
28
30
32
34
35
37
39
40
43
46
48
51
53
Distance along track, m
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200


10 September 2008 06 Pt. Allerton, Hull - Heading, 20s ave., True
Depth, m
-1.0
-1.3
-1.6
-1.9
-2.2
-2.5
-2.8
3
5
8
12
15
17
20
23
25
28
30
32
34
35
37
39
40
43
46
48
51
53
56
61
Distance along track, m
-180
-135
-90
-45
0
45
90
135
180

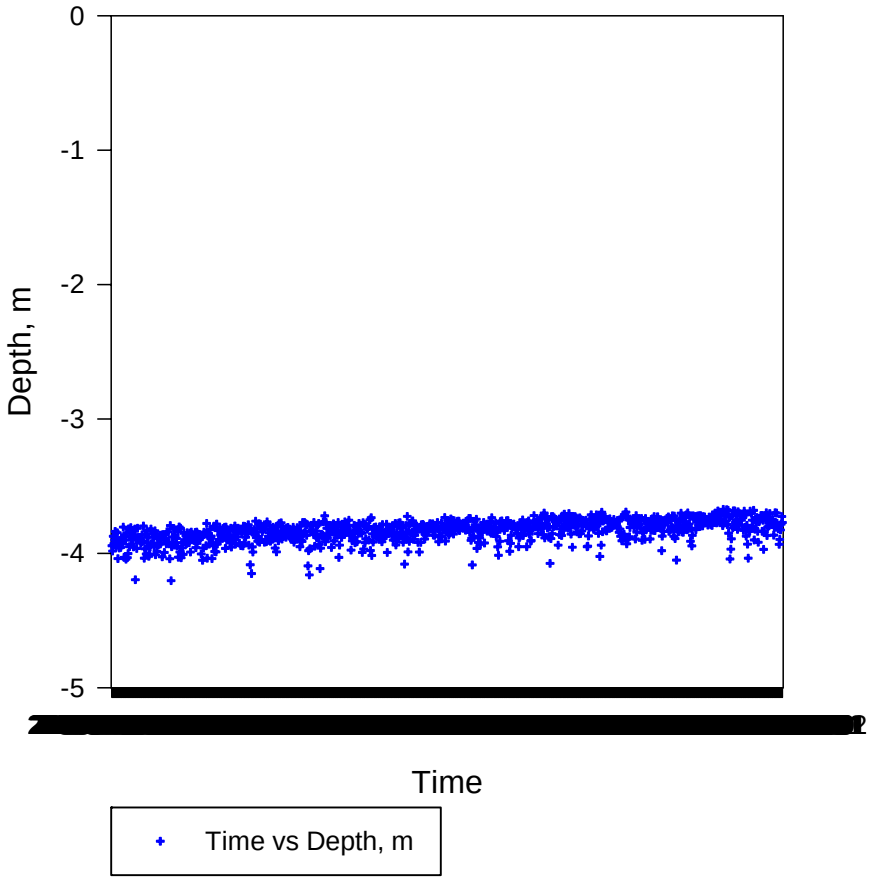
10 September 2008 07 Bumpkin Is. Tidal Flats - Amplitude 20s ave.



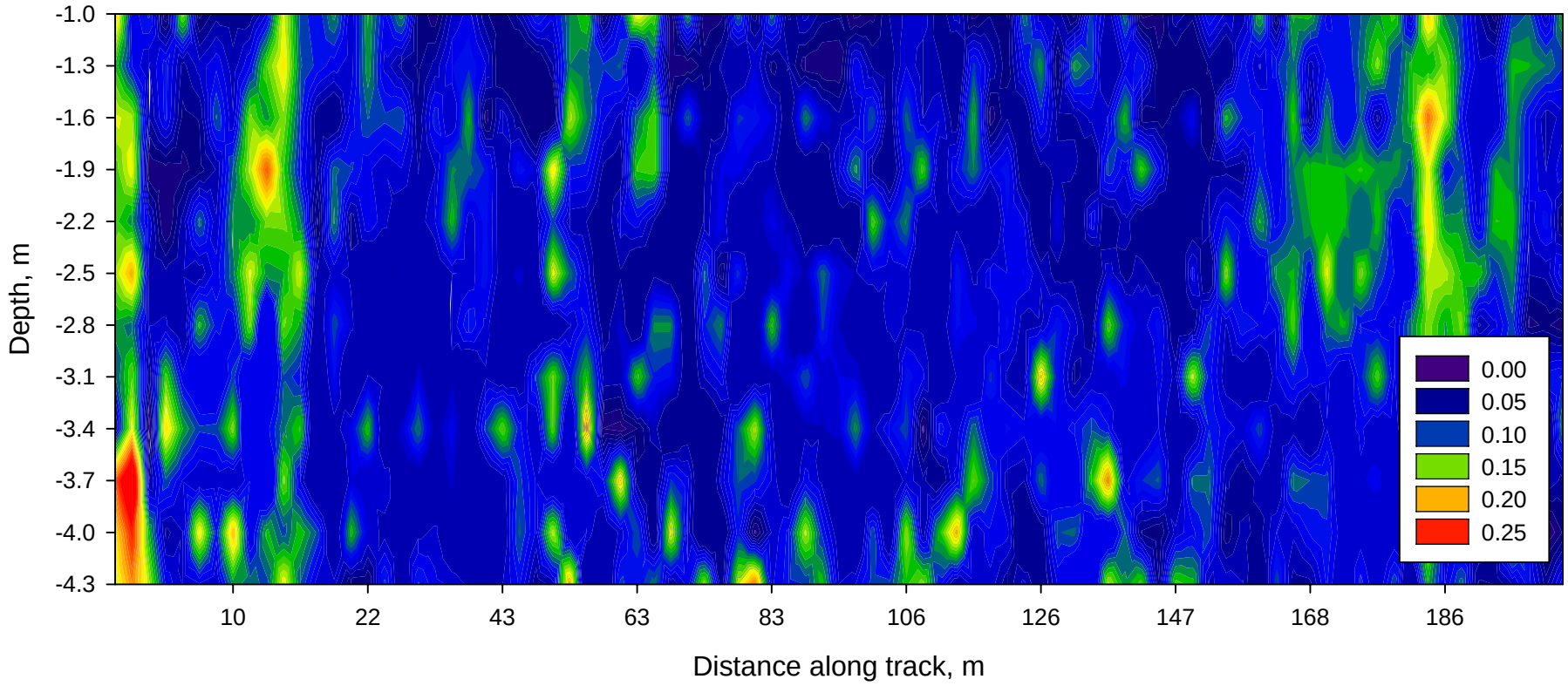
10 September 2008 07 Bumpkin Is. Tidal Flats - Quality



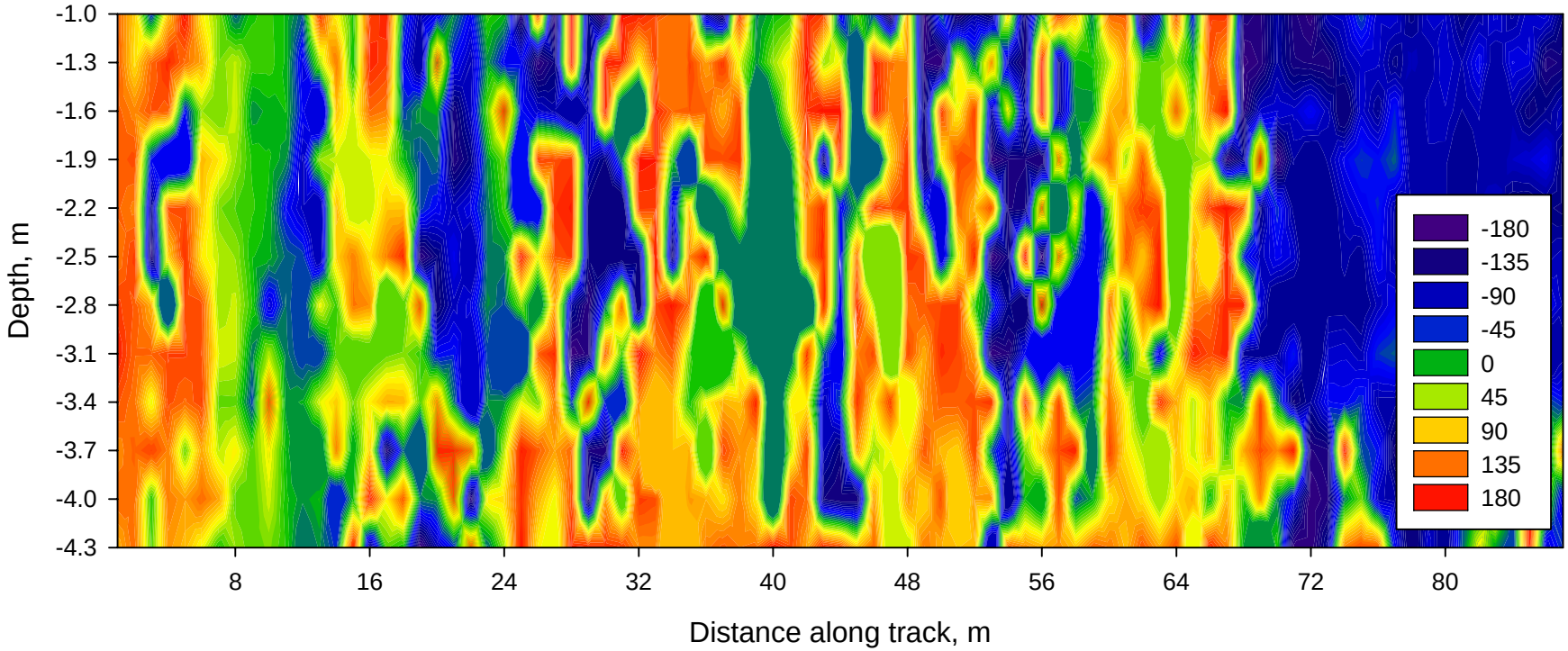
10 September 2008 07 Bumpkin Is. Tidal Flats - Depth



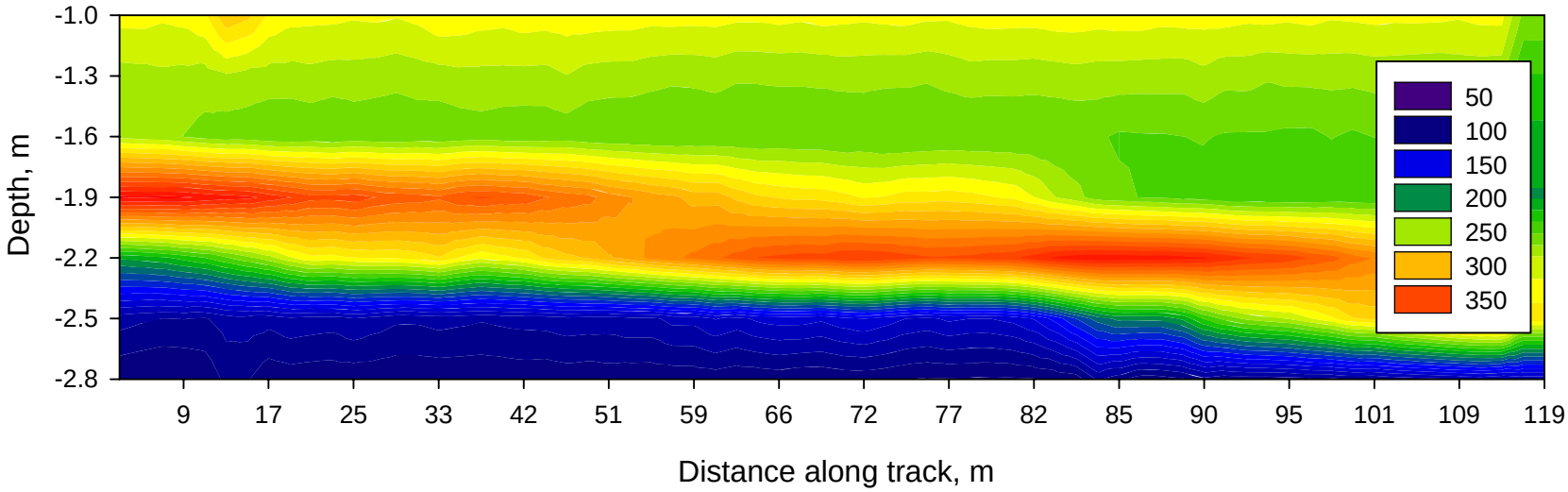
10 September 2008 07 Bumpkin Is. Tidal Flats - Total Speed 20s ave., m/s



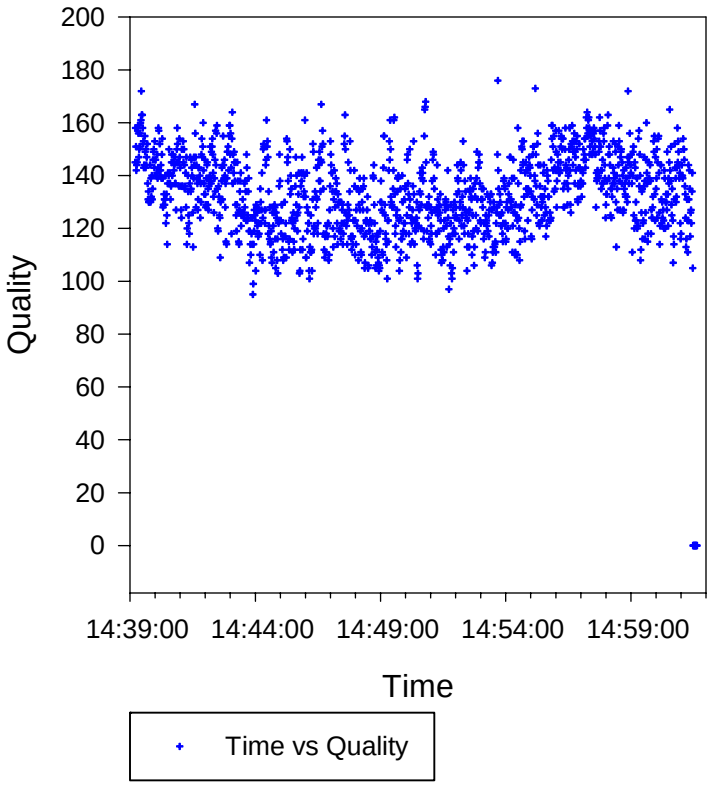
10 September 2008 07 Bumpkin Is. Tidal Flats - Total Heading 20s ave., m/s



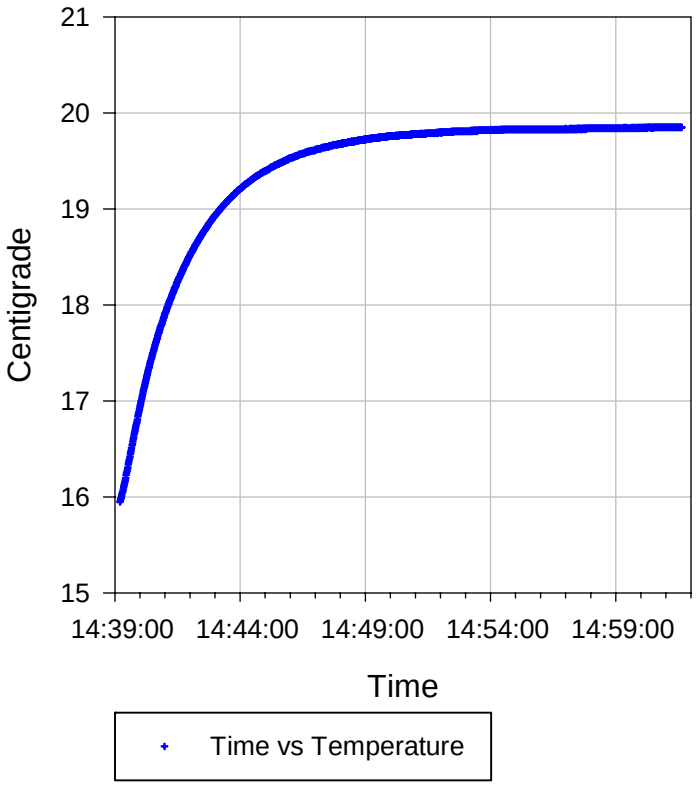
10 September 2008 08 Moon Island Mud Flats - Amplitude 20s ave.



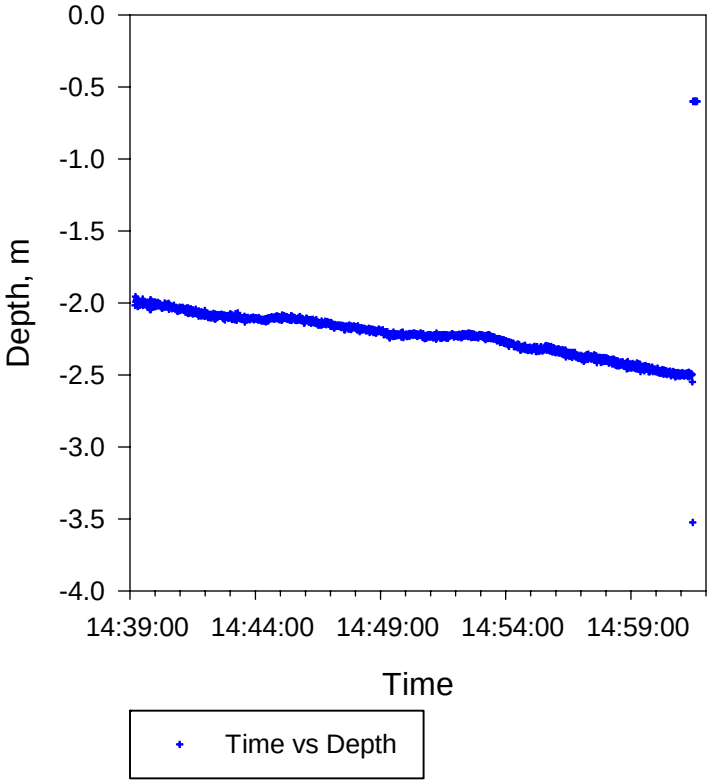
2D Graph 14



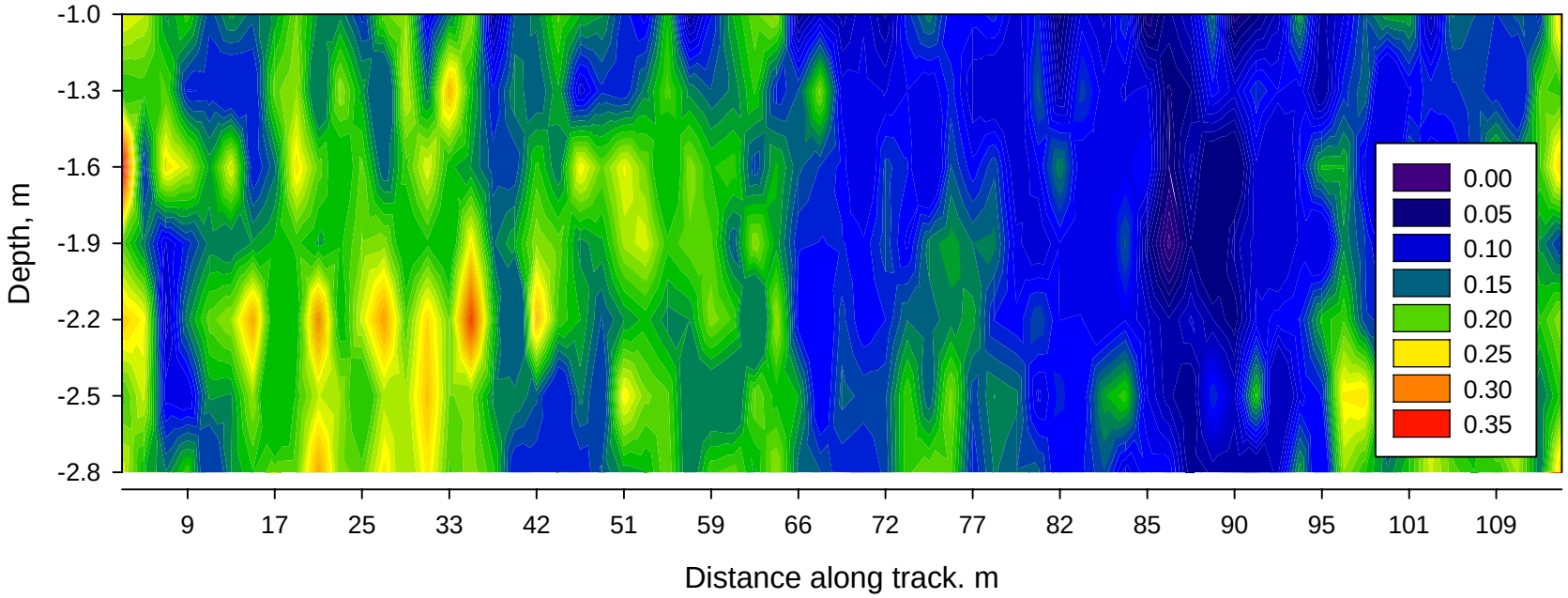
2D Graph 15



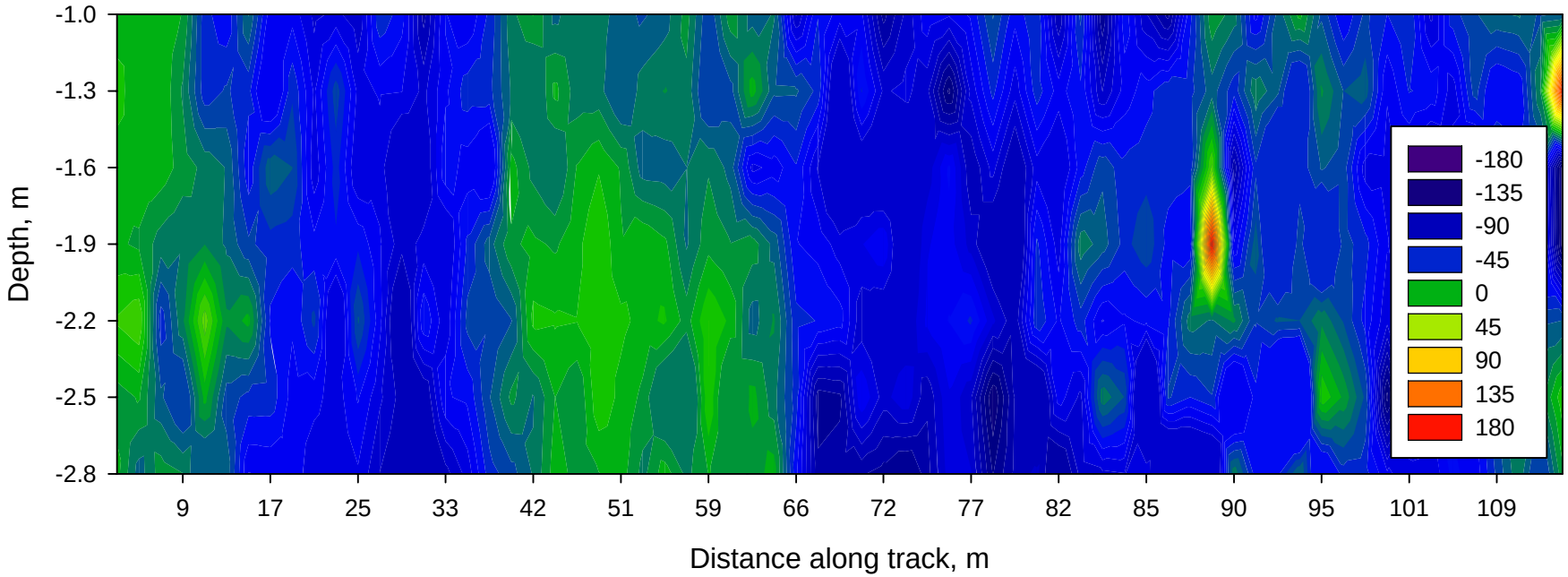
2D Graph 13



10 September 2008 08 Moon Island Mud Flats - Speed 20s ave., m/s



10 September 2008 08 Moon Island Mud Flats - Heading 20s ave., True

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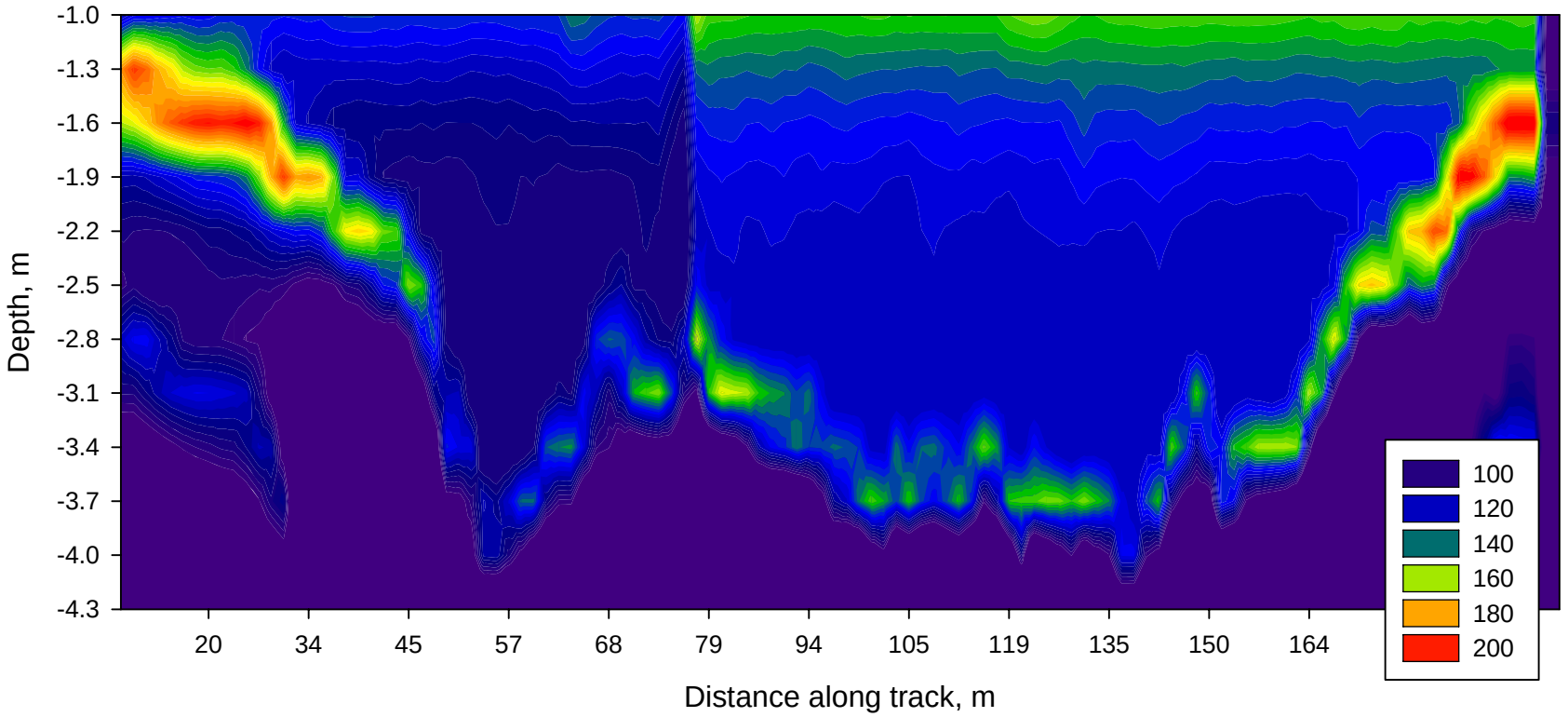
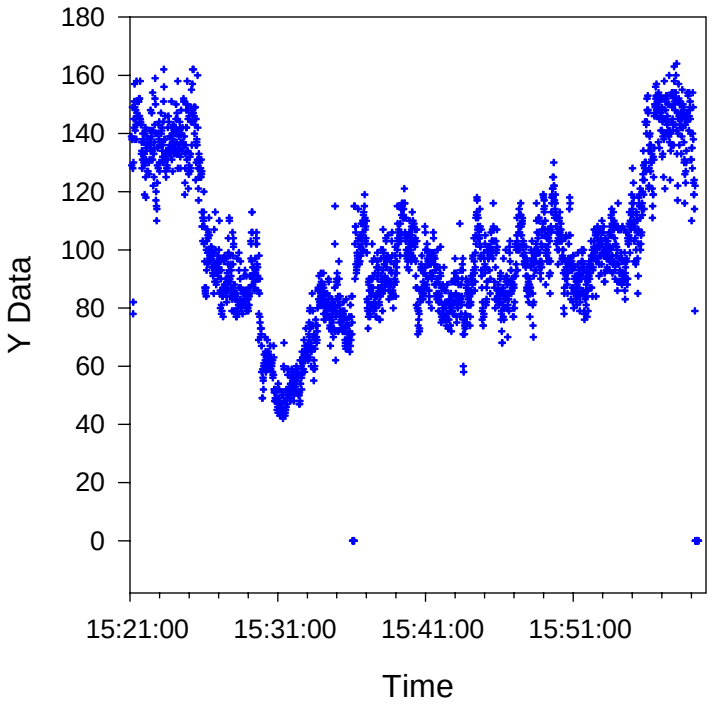
42°18'40.47" N 71°02'24.67" W
elev 0 ft
Jun 2007
Eye alt 629 ft

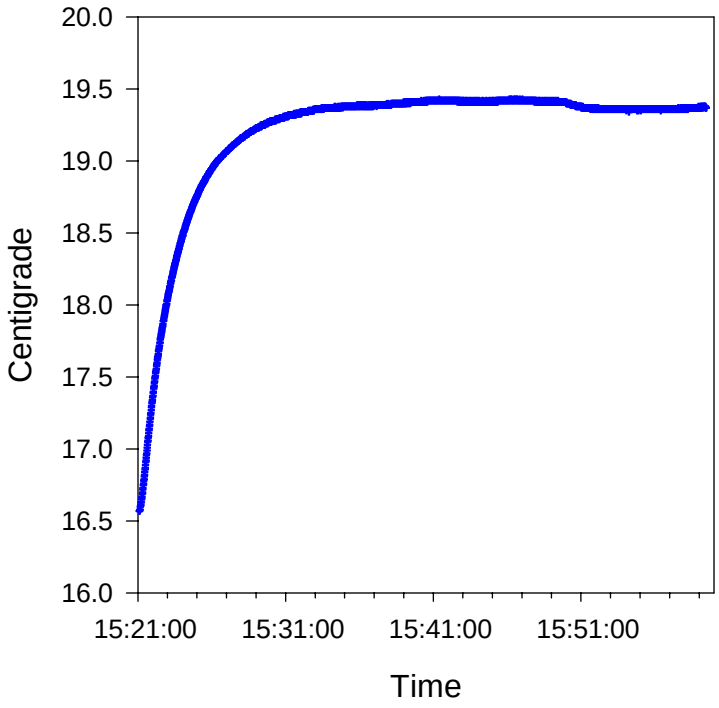
10 September 2008 09 U Mass Marine Ops Basin - Amplitude 20s ave.



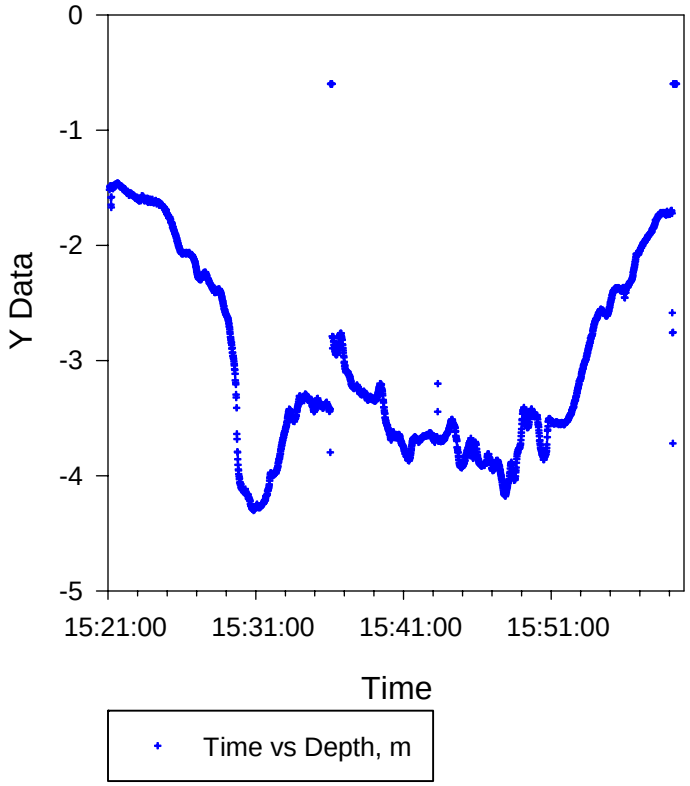
2D Graph 17



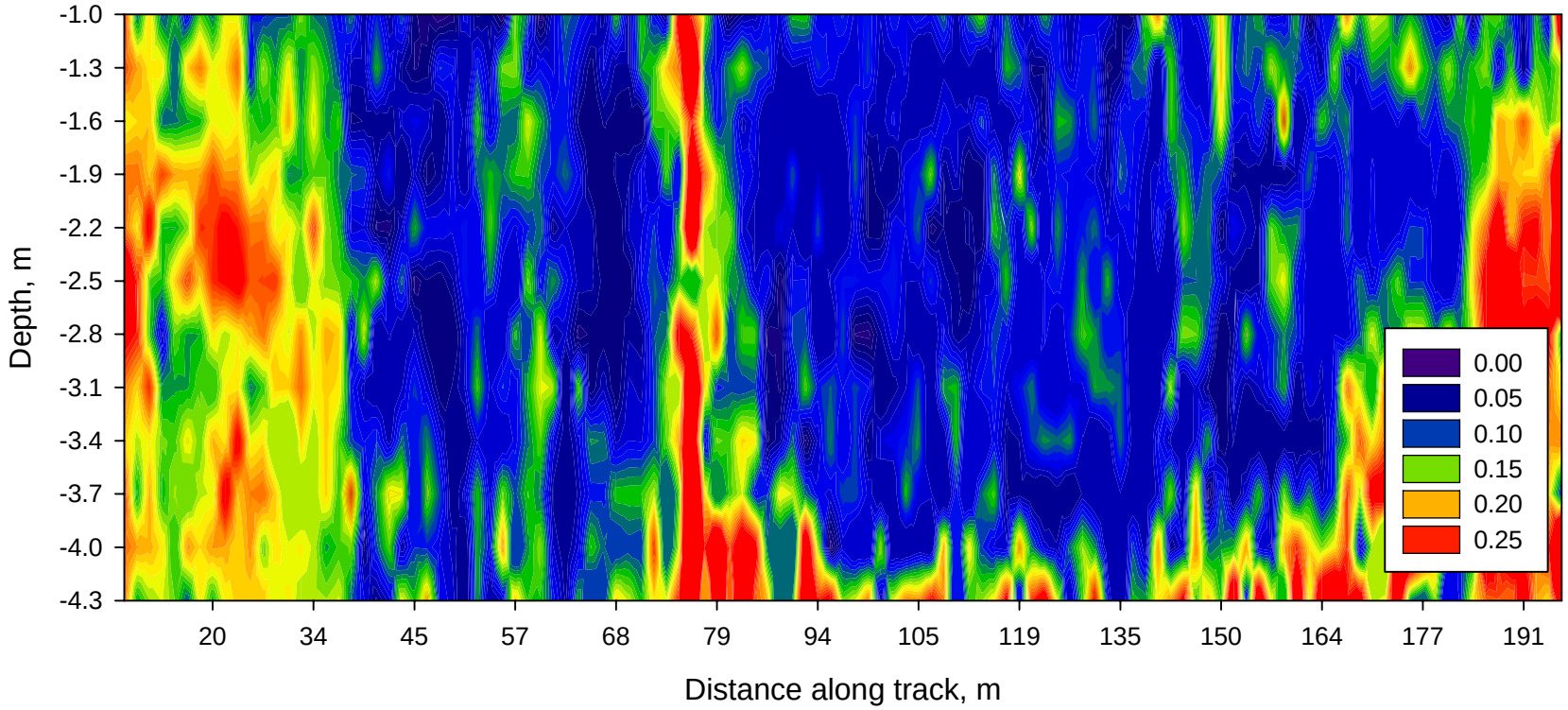
2D Graph 19



2D Graph 16



10 September 2008 09 U Mass Marine Ops Basin - Speed 20s ave., m/s



10 September 2008 09 U Mass Marine Ops Basin - Heading 20s ave., True

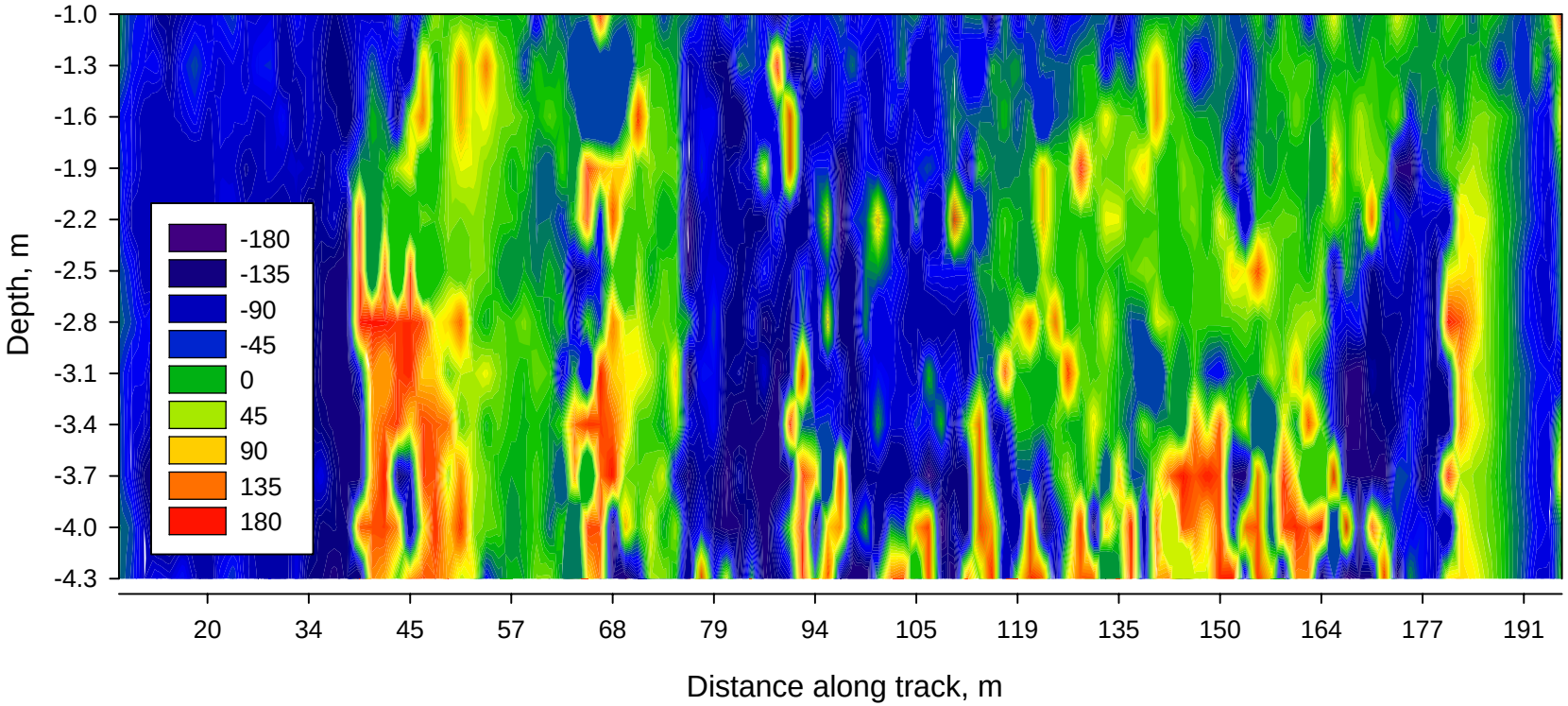


TABLE 5.	Data Processing

GPS Data

- GPS Data Files
  - GPS 1 Hz Sampling
  - GPS Data (CSV)
    - $GPS,V NMEA Code
    - Hh,mm,ss Time UT
    - Latitude * 1E+07
    - Longitude * 1E+07
    - Z, mean sea level, cm
    - Z, ellipsoid, cm
    - COG, deg * 100 True
    - SOG, cm/s
    - Z(t), cm/s
    - Navigation type
    - Satellite list
    - FOM, cm
    - EVPE, cm
    - Clock Bias, ms
    - Clock Drift, mc
    - HDOP, cm
    - Checksum

GPS Data Processing

- Scale latitude and longitude
- GPS velocity
  - SOG and COG
    - Convert COG (true) to COG (enu):
      - E.g. Excel:IF(COG<90,(-1) * COG+90, (-1) * COG+450)
    - Ve = SOG * cos(COG[enu])
    - Vn = SOG * sin(COG[enu])
  - Latitude and Longitude
    - Compute Ve and Vn from great circle distances for (Lon2, Lat2) and (Lon1 - Lat1). See notes.
  - See page below for comparison of tracks from two methods. Direct computation of velocity from SOG and COG seems to give inaccurate results.
  - If desired, vector average Ve and Vn

Aquadopp Data

- Aquadopp Data files
  - Header file
    - Measurements, checksum errors, time interval
  - User set up. See notes.
  - Hardware configuration. See notes.
  - Serial number. See notes.
  - Head configuration. See notes.
  - Data file format. See notes.
  - Sensor file format. See notes for full listing.
  - time: m,d,yyyy,h,m,s
    - Battery volts
    - Sound speed
    - Heading, pitch, roll
    - Temperature, C
  - Velocity related to local magnetic North (ENU)
    - X (East), Y (North), Z Up)

Aquadopp Data Processing

- Convert Vx, Vy in local magnetic ENU to True ENU. Local magnetic variation = Ə.
  - Vx(True ENU):
    - Ve * cos(Ə) – Vn * cos (½ π - Ə)
  - Vy(True ENU):
    - Ve * cos(½ π - Ə) + Vn * cos(Ə)
- Vector add Aquadopp Vx and Vy (True ENU) to GPS Vx and Vy (True ENU) for water column v(x,y)
- Vector average water column velocities to reduce noise.

Aquadopp Profiler specific structures

AQUADOPP PROFILER VELOCITY DATA (variable length)

Size	Name	Offset	Description
1	Sync	0	a5 (hex)
1	Id	1	21 (hex)
2	Size	2	size of structure in number of words (1 word = 2 bytes)
1	Minute	4	minute (BCD)
1	Second	5	second (BCD)
1	Day	6	day (BCD)
1	Hour	7	hour (BCD)
1	Year	8	year (BCD)
1	Month	9	month (BCD)
2	Error	10	error code
2	AnaIn1	12	analog input 1
2	Battery	14	battery voltage (0.1 V)
2	SoundSpeed/AnaIn2	16	speed of sound (0.1 m/s) or analog input 2
2	Heading	18	compass heading (0.1°)
2	Pitch	20	compass pitch (0.1°)
2	Roll	22	compass roll (0.1°)
1	PressureMSB	24	pressure MSB (mm) (Pressure = 65536×PressureMSB + PressureLSW)
1	Status	25	status code
2	PressureLSW	26	pressure LSW (mm) (Pressure = 65536×PressureMSB + PressureLSW)
2	Temperature	28	temperature (0.01 °C)
2	Vel 1 B1/X/E	30	velocity cell 1, beam1 or X or East (mm/s)
2..	Vel 2⋯n	32⋯	...repeated for cells 2 through n
2	Vel 1 B2/Y/N		velocity cell 1, beam2 or Y or North (mm/s)
2..	Vel 2⋯n		...repeated for cells 2 through n
2	Vel 1 B3/Z/U		velocity cell 1, beam3 or Z or Up (mm/s)
2..	Vel 2⋯n		...repeated for cells 2 through n
1	Amp 1 B1		amplitude cell 1, beam1 (counts)
1..	Amp 2⋯n		...repeated for cells 2 through n
1	Amp 1 B2		amplitude cell 1, beam2 (counts)
1..	Amp 2⋯n		...repeated for cells 2 through n
1	Amp 1 B3		amplitude cell 1, beam3 (counts)
1..	Amp 2⋯n		...repeated for cells 2 through n
1	Fill		fill byte if number of cells mod 2 is not equal to 0
2	Checksum		= b58c(hex) + sum of all bytes in structure